CHARLES GRIFFIN & CO., LTD., Publishers.

In Large 8vo. Handsome Cloth. Profusely Illustrated. 8s. 6d. net.

WIRELESS TELEGRAPHY.

BY DR. GUSTAVE EICHHORN.

CONTENTS.—Oscillations.—Closed Oscillation Systems.—Coupled Systems.—The Coupling Compensating the Aërial Wire.—The Receiver.—Comparative Measurement in the Sender.—Theoretical Results and Calculations in respect of Sender and Receiver.—Closely Coupled Sender and Receiver.—Loose Coupled Sender and Receiver.—Principal Formulæ.—The Ondameter.—Working a Wireless Telegraph Station.—Modern Apparatus and Methods of Working.—Conclusion.—Bibliography.—INDEX.

SECOND EDITION, Revised. In Large 8vo. Profusely Illustrated. 24s. net.

CENTRAL ELECTRICAL STATIONS:

THEIR DESIGN, ORGANISATION, AND MANAGEMENT.

BY CHAS. H. WORDINGHAM, A.K.C., M.I.C.E., M.I.M.E.

ABRIDGED CONTENTS.—Introductory.—Central Station Work as a Profession.—As an Investment.—The Establishment of a Central Station.—Systems of Supply.—Plant.—Boilers.—Systems of Draught and Waste Heat Economy.—The Transmission of Steam.—Generators.—Condensing Appliances.—Switching Gear, Instruments, and Connections.—Distributing Mains.—Insulation, Resistance, and Cost.—Distributing Networks.—Service Mains and Feeders.—Testing Mains.—Meters and Appliances.—Standardising and Testing Laboratory.—Secondary Batteries.—Street Lighting.—Cost.—General Organisation.—Mains Department.—Installation Department.—Standardising Department.—Drawing Office.—Clerical Department.—The Consumer.—Routine and Main Laying.—INDEX.

In Large 8vo. Cloth. Very Fully Illustrated. 12s. 6d. net.

ELECTRICITY CONTROL.

A TREATISE ON ELECTRIC SWITCHGEAR and SYSTEMS OF ELECTRIC TRANSMISSION.

BY LEONARD ANDREWS, A.M.I.C.E., M.I.E.E.

General Principles of Switchgear Design.—Constructional Details.—Circuit Breakers or Arc Interrupting Devices.—Automatically Operated Circuit Breakers.—Alternating Reverse Current Devices.—Arrangement of 'Bus Bars and Apparatus for Parallel Running.—General Arrangement of Controlling Apparatus for High Tension Systems.—General Arrangement of Controlling Apparatus for Low Tension Systems.—Examples of Complete Installations.—Long Distance Transmission Schemes.

Large 8vo. Cloth. With 334 pages and 307 Illustrations. 16s. net.

ELECTRICITY METERS.

BY HENRY G. SOLOMON, A.M.INST.E.E.

CONTENTS.—Introductory.—General Principles of Continuous-Current Meters.—Continuous-Current Quantity Meters.—Continuous-Energy Motor Meters.—Different Types.—Special Purposes, *i.e.*, Battery Meters, Switchboard Meters, Tramcar Meters.—General Principles of Single- and Polyphase Induction Meters.—Single-phase Induction Meters.—Polyphase Meters.—Tariff Systems.—Prepayment Meters.—Tariff and Hour Meters.—Some Mechanical Features in Meter Design.—Testing Meters.—INDEX.

EIGHTEENTH EDITION. Leather, Pocket Size, with 764 pages. 8s. 6d.

A POCKET-BOOK OF
ELECTRICAL RULES AND TABLES

FOR THE USE OF ELECTRICIANS AND ENGINEERS.

BY JOHN MUNRO, C.E., & PROF. JAMIESON, M.INST.C.E., F.R.S.E.

Units of Measurement.—Measures.—Testing.—Conductors.—Dielectrics.—Submarine Cables.—Telegraphy.—Electro-Chemistry.—Electro-Metallurgy.—Batteries.—Dynamos and Motors.—Transformers.—Electric Lighting.—Miscellaneous.—Logarithms.—Appendices.

Catalogue of Engineering, Mining, Metallurgical, Technological, and Nautical Works may be had Post Free on Application.

LONDON: CHARLES GRIFFIN & CO., LIMITED, EXETER STREET, STRAND.

THE JOHN CRERAR LIBRARY

TELEGRAPHIC SYSTEMS
AND OTHER NOTES.

BY

ARTHUR CROTCH,

SILVER MEDALLIST AND HONOURSMAN IN TELEGRAPHY, AND HONOURSMAN IN TELEPHONY, CITY AND GUILDS OF LONDON INSTITUTE; SOME TIME LECTURER ON THESE SUBJECTS AT THE MUNICIPAL TECHNICAL SCHOOLS, NORWICH.

With 222 Illustrations.

LONDON:
CHARLES GRIFFIN & COMPANY, LIMITED;
EXETER STREET, STRAND.
1908.

[*All Rights Reserved.*]

A 20

CHAPTER VII.

THE HUGHES TYPE-PRINTING INSTRUMENT.

We now come to quite a different class of apparatus to that which we have hitherto considered. In the Morse system the signals consist of combinations of currents of long and short duration, representing the letters of the alphabet by a prearranged code, and these combinations have to be translated at the receiving end and the message written down. In the Hughes system the received signals are translated by the receiving mechanism and printed automatically in Roman type on a paper slip. No receiving operator (as a translator and writer) is thus required. It also has the advantage that the sending and receipt of a message are simultaneous.

Further, the combinations of the Morse alphabet are of varying length. The Hughes signals are all of the same length, each letter consisting of an impulse of current. These impulses are separated by varying intervals of time—the intervals and signals being of equal importance in the scheme. Thus a portion of these must be added to the actual length of the impulse in order to institute a comparison between the working lengths of the signals of the two systems.

The Hughes instrument, in its receiving portion, consists essentially of a continuously-revolving inked wheel, carrying the letters of the alphabet on its periphery, and a paper tape just clear of the wheel. When an impulse of current is received, the paper is raised into momentary contact with the wheel and that letter is printed which is opposite the paper at the time. By the rotation of the type-wheel every letter of the alphabet in turn is brought opposite the slip: the currents sent must, therefore, be so timed as to raise the slip when the required letter is opposite. At the sending end a contact lever, when depressed, makes the necessary connection between the battery and the line, and this lever is actuated by keys, through the intermediation of another simple piece of apparatus which determines the exact time at which the signal shall be sent. In each complete instrument the means both of sending and receiving are included; indeed, when the apparatus is sending, its receiving portion is invariably actuated also, so as to give the operator a check upon his sending.

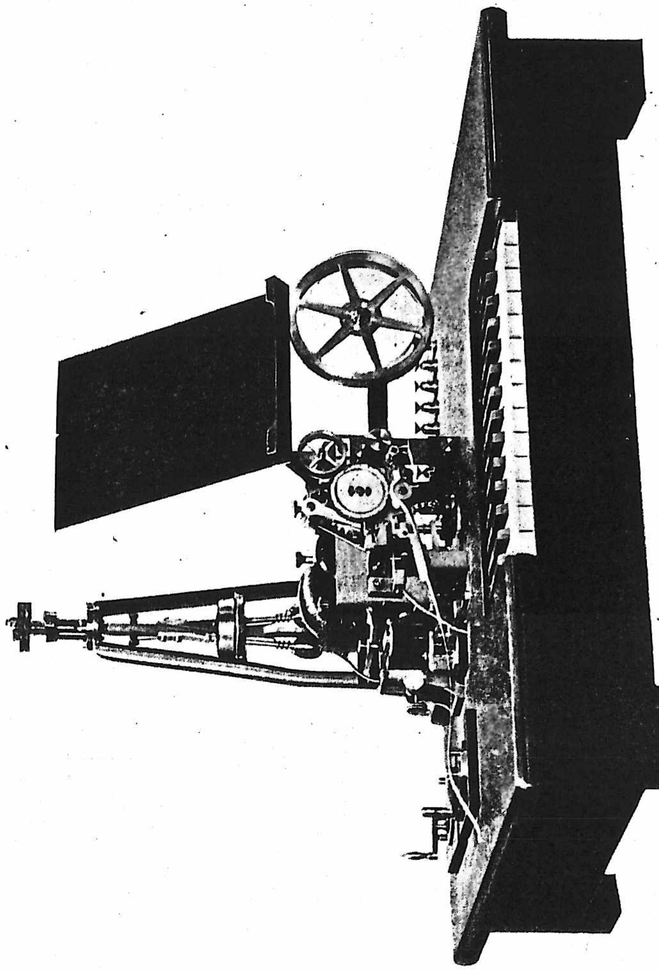


Fig. 100.—Hughes instrument.

The general appearance of the instrument is seen in Fig. 100. Fig. 101 is a front elevation and a section of some of the under

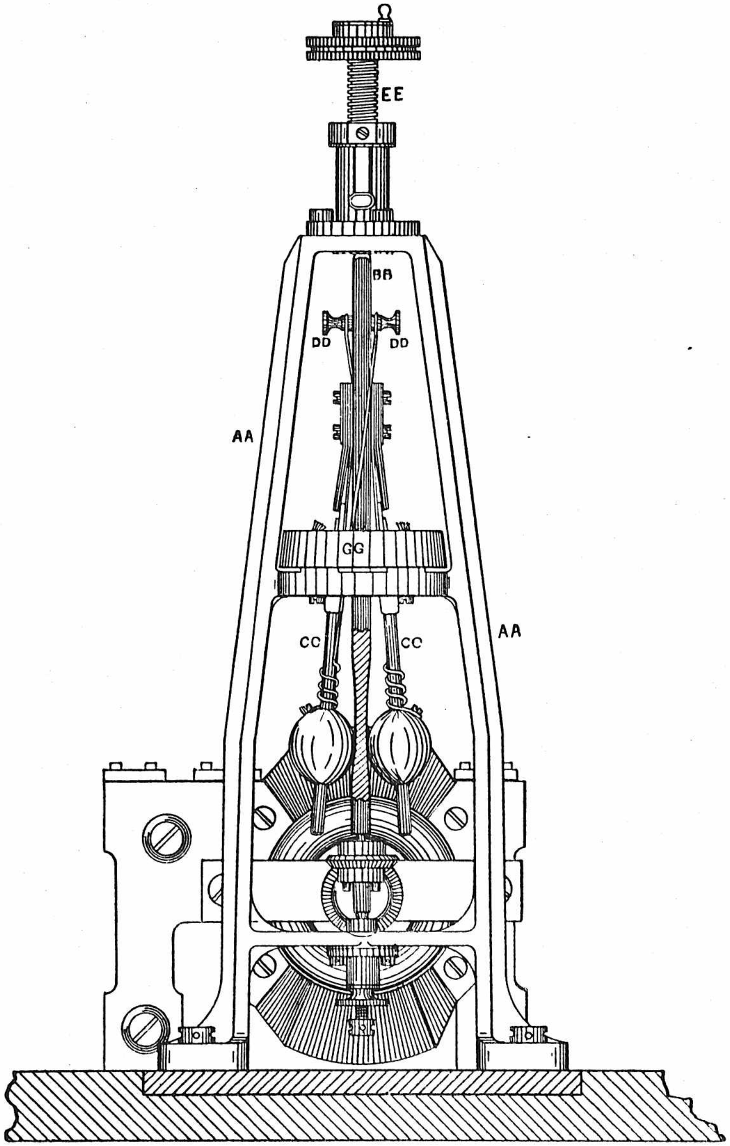


Fig. 107.—Motor and governor.

G G, thus introducing friction. The actual speed at which the instrument runs is from 100 to 125 revolutions of the chariot per minute.

General.—From Fig. 108 it will be seen that the path of the received current through the apparatus is from the line terminal, the contact lever, the lower contact, the motor switch (the motor running, hence this switch to the "on" position), *via* framework of instrument, to detent arm P and the corecting cam *c*, thence by the spring Y through motor switch again, and to the 5-position switch. Assuming this to be at position 1, the current passes through the electro-magnet coils to earth. The armature itself is connected to earth through the resistance coil; as soon, therefore, as A is released, it makes contact with the detent arm,

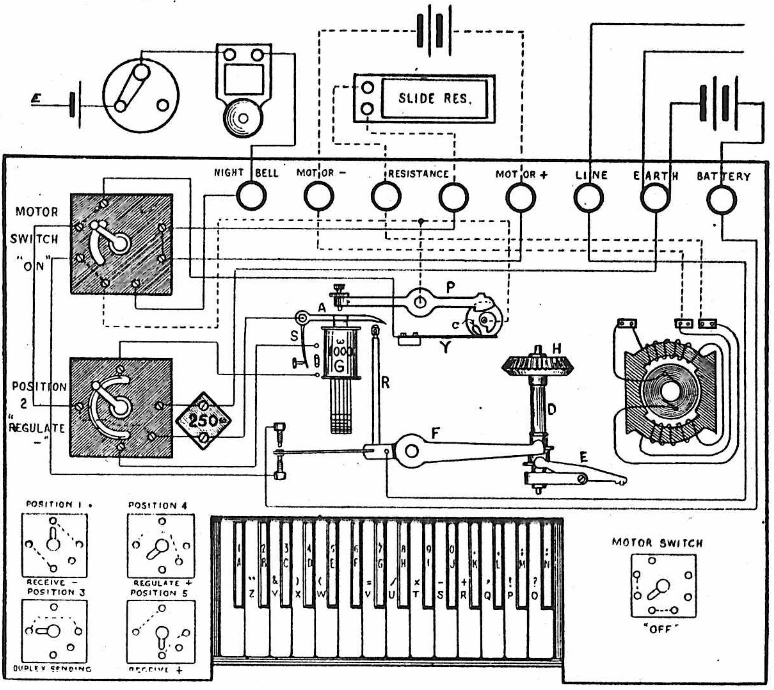


Fig. 108.

CHAPTER IX.

THE MURRAY TYPE-PRINTING TELEGRAPH.

In this system the only skill employed is that of a typist at the sending end. This operator, who need not be a telegraphist, types the messages on an ordinary keyboard, but instead of appearing in the usual characters on a form, the message comes out in arbitrary signs on a perforated slip. Here the skill ends: all the rest being electrical and mechanical. The prepared slip is passed through a species of Wheatstone transmitter, which sends, in obedience to the perforations in the former, currents of varying length and direction. At the receiving end, these signals cause a similar slip to be perforated. This slip, in its turn, being passed through (at leisure) an attachment to a typewriter, actuates the keys of the latter, and the message is automatically typed on a form.

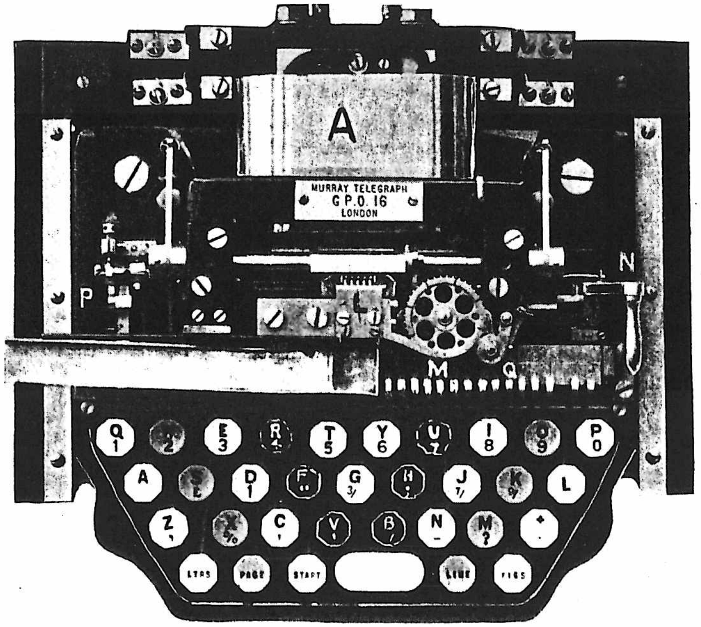


Fig. 126.—Murray perforator.

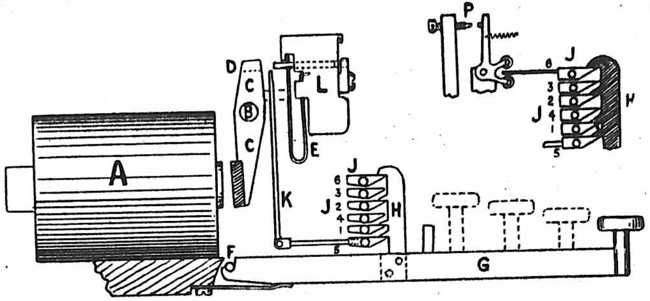


Fig. 127.

These operations naturally fall into three divisions—(*a*) the typing with its resulting perforated tape; (*b*) the electrical transmission over the line and through the receiving apparatus, resulting in the second perforated tape; and (*c*) the rendition of the signals on the latter into ordinary typewritten characters.

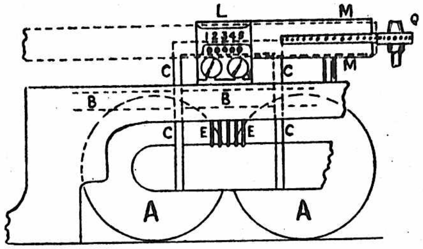


Fig. 128.

Perforator, or typewriting perforator.—This is shown in Fig. 126, whilst Figs. 127 and 128 give details as seen from the side and front. It is provided with a wooden base and cover, but these are removed in order to show the more essential parts with greater clearness. A keyboard of 33 keys occupies the front. At the back is a powerful electro-magnet, A, which is energised whenever a key is struck. A is enclosed within a thin metallic case, presenting the appearance shown in Fig. 126. An axle, B, runs across the back of the keyboard, being carried in two bearings. At each end is an arm, to the extremity of which is fastened a strong spiral spring, keeping the axle in a certain position. On this axle is a frame, C, carrying at its lower part the armature of the electro-magnet, and at its upper part a bar D. This bar is normally kept drawn backwards, and the armature off the electro-magnet poles, by the tension of the spiral springs before-mentioned. Immediately in front of D is the punch-block L, in which is a horizontal row of five punches, normally drawn backwards by five U-shaped springs E. Whenever a key is depressed the electro-magnet attracts the armature and the bar D moves forward, tending to strike the punches forward. Its travel, however, is not quite sufficient to enable it to reach them.

Each of the keys G is pivoted at F, and is kept up by the pressure of a flat spring. Each key carries a vertical arm, H, whose back edge is furnished with one to six hooks or catches, and immediately behind the series of arms is a set of six stout steel strips, J, pivoted as shown in Fig. 127. On the back edge of each strip, J, is a horizontal arm, to which is connected an upright rod, K. Only one of these is shown. The upper end of K is flattened, and normally rests just below and at the back of the punches. When, therefore, any key is put down, the hooks on its vertical arm H will depress the forward edge of one or more of the strips J. The back edge will rise and push up its rod K, so that the end is between the bar D and one of the punches. This action takes place at the initial stage of the downward movement of the key. The completion of the movement closes the circuit of the electro-magnet, the bar D moves forward, and by means of the ends of any rods, K, which have been raised, is enabled to strike the required punches and perforate the slip.

The hooks on the arms H are different in number and position for each key, excepting that all actuate the top strip 6, whose function is to close the contact P of the electro-magnet seen separately on the right of Fig. 127. This strip, therefore, has no rod, K. The others are arranged to raise one, two &c., or all of the remaining five strips, and thus enable the striker bar D to actuate any desired punch or group of punches.

To the right of the punch-block L in Figs. 126 and 128 is the star- or feed-wheel M, whose normal function is to feed the slip forward. This is urged round in a clockwise direction one letter space (5 units) by the return of the armature system after striking the punches. It will be seen that M is marked off into eight complete spaces, each of which contains five teeth. The slip is similarly marked, and on inserting the end of a roll care has to be taken that the marks on the slip and those on the wheel correspond.

On the right of M (Fig. 126) is an arm, N, which, on being pushed to the left, causes the star-wheel to rotate one letter space in the reverse direction to its ordinary movement, and it thus brings back the slip one letter. This is for use when a letter or word has been wrongly punched. Without this device the error, although indicated later, would be printed on the message form at the receiving end along with the correction. By means of this device, however, the paper is drawn back, one letter for each movement of N, to the required extent, and the "letters" signal punched repeatedly. This causes all the punches to be operated, and each space on the slip is thus perforated with five holes—that is, whatever spaces were left in the previous operation are now punched with holes, entirely obliterating the former characters. At the receiving end, as we shall see, this causes no record whatever to be made, so that, in the finished message, no trace of the error appears.

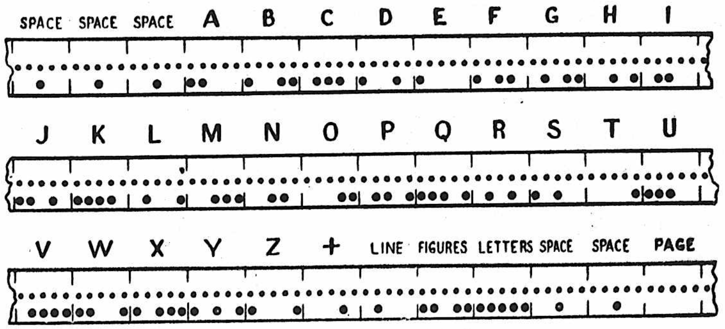


Fig. 129.—Murray alphabet.

Murray Alphabet.—Like the Baudot, this is an equal-letter 5-unit alphabet. The slip, before insertion in the perforator, has been centre-holed and marked, as shown in Fig. 129. Each of these divisions has thus five positions, and is occupied by a single letter. The depression of the key "E" tilts strip J, No. 1, and causes No. 1 punch to perforate the strip with a hole in the first position of one division of the tape. The depression of the "space" key actuates strip 3, and causes a hole to be punched in the third position of another division. The key labelled "letters," if depressed, causes five holes to be punched, and so on.

With a 5-unit alphabet 31 combinations are possible. These are appropriated as follows:—26 for the alphabet, the sign +, the "space" signal (between words), and the "line" signal = 29.

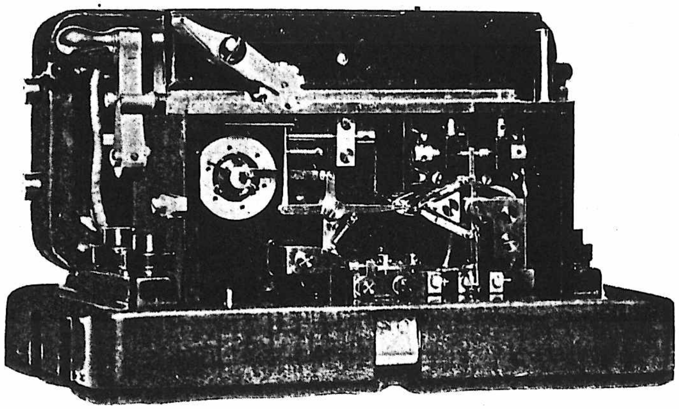


Fig. 130.—Transmitter: front.

But it will be seen that, in addition to a letter, each key carries a figure or a sign. It is, therefore, arranged that, by prefixing a suitable signal, all the above 29 shall indicate a new series of figures and signs. This signal is punched by the key labelled "figures," and, to bring back the letter series, another signal is punched by the depression of the key marked "letters." Thus, for 29 signs, we obtain 58 characters.

With an ordinary typewriter, when the end of a line is approaching, a warning bell rings. This is also arranged for, and, as the receiving apparatus is required to start a fresh line at the proper place, the "line" key is depressed to effect this.

The key marked "page" does not actuate any of the punches, but energises the electro-magnet as usual, and thus feeds the paper forward. At the receiving end it serves as a stop signal.

Transmitter.—The slip having been prepared, we have to consider the transmitter. This, known as the "single-line" instrument, because only a single row of (signalling) holes is punched on the slip, is shown in Figs. 130, 131, and 132. The first is a front view, the second a back view, showing the motor, and the third a diagram of the instrument.

An upright arm, A, is mounted on a pin, G. Its upper end is connected by a rod to the disc D, carried on an axle which protrudes through the front of the instrument, and which is kept constantly rotating in the direction shown. Its rate is such that it makes five revolutions for each letter on the slip, or one per unit. The upper end of A, therefore, moves to the right and left alternately. Pivoted on A is a horizontal arm, B, whose left-hand end is connected to the rod C. A shoulder on B normally banks against a pin on A under the tension of a spiral spring connecting the two arms. If it be free to do so, the system A B will move as one. H is the contact lever moving between two stops, M and S. By reason of the pressure of the jockey-wheel J upon its lower edge, the lever cannot maintain an intermediate

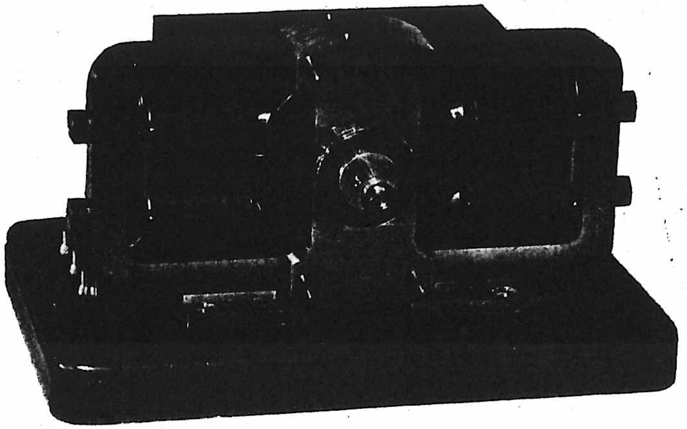


Fig. 131.—Transmitter: back, showing motor.

position. Hence, when it is pushed over to one side, it remains there until it is thrust over to the other. F is a forked attachment by which it is moved by the arm B.

As A moves to the right, B necessarily shares the movement. If the rod C be free to rise (through a perforation in the slip) the right-hand end of B will not only move towards F, but also in a downward direction. It, therefore, butts against the end of the lower arm of F, which is slightly hollowed or concave. This forces H over to the marking contact. If the rod C encounters unpunched slip it cannot get through, and the end of B has an upward movement. With the lever in the position shown in Fig. 132, B will not quite reach the upper arm of F, as it is already in the position to which B would move it.

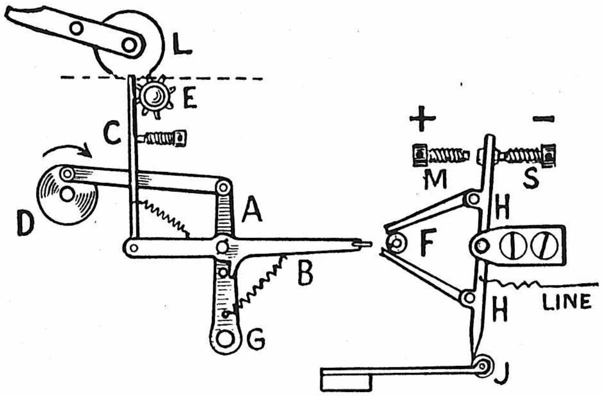


Fig. 132.

If the instrument were run without slip the rod C would ascend; H would be pushed over to marking in the first revolution of D, and would remain there. In order that reversals may be sent out when no slip is inserted, the wheel L, engaging with E, is capable of a slight forward movement by which it presents to the rod C a solid and a cut-away portion alternately, so as to allow the rod to rise at one revolution and to prevent it at the next. With L in its normal running position the wheel is cut away entirely in the path of C, so that the latter may rise whenever a perforation in the slip allows. If two perforations occur together, or two unperforated units, the lever simply remains over where it was last placed. The components of a letter, if of similar sign, thus run into each other, and similarly with adjacent letters.

Motor and Transmitting Vibrator (driving reed).—The transmitter is driven by a small synchronous motor—the "phonic wheel" of Chapter VI. This can be seen in the back view of the instrument in Fig. 131. The wheel has seven teeth and two electro-magnets. The intermittent currents for driving the wheel are sent from the "transmitting vibrator" of Fig. 133. This is a steel bar firmly clamped at one end and carrying an adjustable weight or "bob" at the other. It has a contact on either side which completes the circuit of the opposite electro-magnet and thus maintains the reed in vibration. Each of the motor magnets is in series with one of the reed magnets, so that the two latter are alternately excited by the movements of the reed. This is seen in Fig. 134.

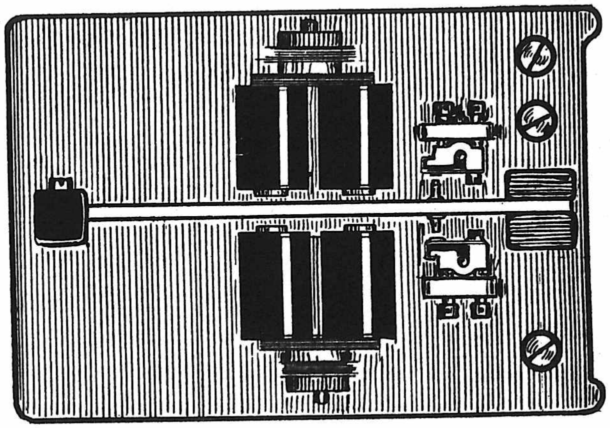


Fig. 133.—Transmitting vibrator.

Receiving Apparatus.—The line signals are received on an ordinary standard relay, and the receiving instruments are placed in the local circuit of this relay. We shall describe and illustrate the several instruments, but their functions can only be properly understood when we consider their concerted action.

Receiving Vibrator or reed.—This illustrated in Fig. 135 is

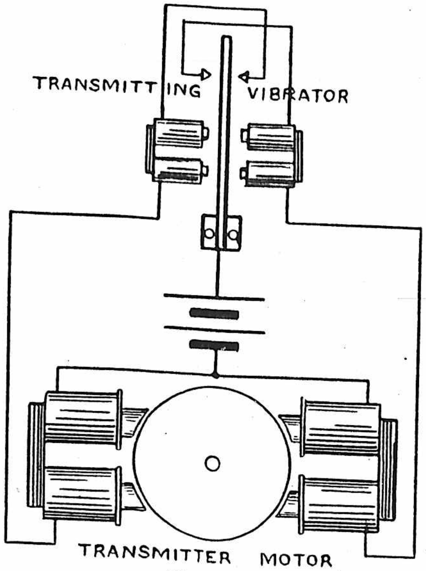


Fig. 134.

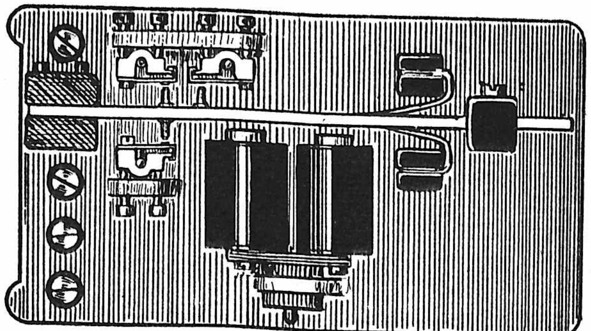


Fig. 135.—Receiving vibrator.

similar to the driving reed of Fig. 133, excepting that it is provided with a pair of brass "buffer" springs, whose tendency is to imprison the reed or to oppose its vibration. It is actuated by a single electro-magnet. For successful working it is necessary to maintain perfect accord between the sending and the receiving apparatus. The reed is adjusted to have a tendency to run slightly fast, whilst the action of the springs tends to retard its motion. When the acceleration reaches an appreciable amount it results in the shortening of the impulses given to the reed by its driving battery. The springs thus have a greater relative effect and check the acceleration.

Local Relays.—These are the punching relay and the governing relay, each a plain electro-magnet whose armature is held off the cores by a spiral spring. They are placed in series with each other and with a battery, in the local circuit of the receiving relay. Thus, whenever the tongue of the latter goes to marking, both relays are actuated. The punching relay has a single contact which is closed by the attraction of the armature. The governing relay armature has two contacts and these are connected together. The local circuit is thus complete, whether the armature is at rest or attracted, but is subject to short breaks whilst the armature is passing from one contact to the other. This break is the means by which the vibrations of the receiving reed are retarded or governed.

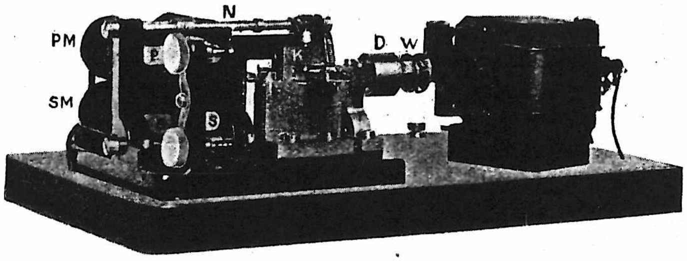


Fig. 136.—Murray recorder.

Recorder.—This consists of the punching and spacing electro-magnets, the punching mechanism, and an electric motor, mounted on a single base, as in Fig. 136. Fig. 137 is also a view of the two magnets and other parts as seen from the motor end of the recorder.

The punching magnet P M is placed above the spacing magnet S M, and its armature, P, is rigidly connected to the shaft N above it, the latter also carrying an arm at the end of which is the punch, moving in the punch-block K. When the armature P is attracted by the passage of a momentary current through the coils, the punch is driven downwards through the slip which passes in the horizontal space between the upper and lower portions of the block. The punch is withdrawn by a spring. The armature S of the spacing magnet is mounted in a similar manner on another shaft, R, below it. R also carries a two-armed pawl, V, engaging with a ratchet-wheel, Q. When S is attracted the pawl moves to the right, and between the disengaging of its right arm and the engaging of its left with Q the latter slips round a certain distance. When S is released Q slips round a further distance, and by these two motions the slip is fed forward. The movement is effected in the following manner:—The motor shaft terminates in a kind of metallic reel, W, which carries two flat springs, on the ends of which are two felt pads or brushes. In exact alignment with the motor shaft, but quite separate from it, is the shaft carrying the ratchet-wheel Q and a star-wheel by which the slip is propelled forward. This shaft carries a loose drum, D, the two being connected by a flat spiral spring which occupies a portion of the inner space of the drum. The two felt brushes carried by W engage with the inner surface of D with considerable friction. The drum shaft is held immovable by its ratchet-wheel Q, but the motor is continually running. The friction between the brushes and the drum is sufficient to carry D round with them, and thus to *wind up* the spiral spring. This goes on until it is quite wound up, when the brushes simply slip round inside D without moving it. When, now, the armature S moves either to or from the cores, and thus allows two short intervals of freedom to Q, the latter slips round under the tension of the wound-up spring. The sum of the movements due to the attraction and release of the armature is such as to give the slip a movement of one-fifth of a letter space. Thus, whenever the punching magnet is energised, a hole is punched in the slip, and when the spacing magnet is actuated the slip is advanced unit distance. The function of the motor is simply to keep the spiral spring wound up.

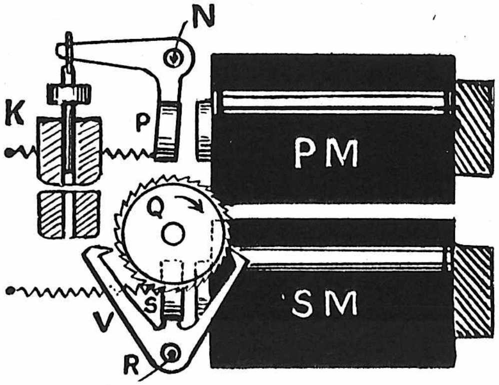


Fig. 137.—Recorder: details.

Concerted Action of Receiving Apparatus.—Fig. 138 shows the assemblage of the instruments we have just described. The reed R, with the battery X, is arranged so that a movement to one side completes the circuit of the spacing magnet. A movement to the other side, if the punching relay contact be closed, completes the circuit of the punching magnet. If the relay contact be kept closed, and the reed kept in vibration, the punching and spacing magnets will be actuated alternately, and the slip will be perforated and drawn forward—a perforation occurring opposite each hole of the central row of guide holes. The punching relay, however, is under the control of the receiving relay F. If the tongue of the latter be kept over to marking—say by the continuous current due to a succession of "letter" blanks—the recorder slip will be perforated, as we have already considered. If the tongue of F be to spacing, the punching relay

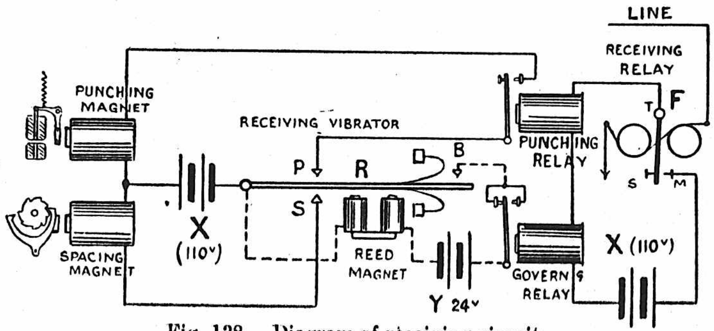


Fig. 138.—Diagram of receiving circuit.

armature will remain at rest, and the punching magnet circuit will be incomplete when the reed makes contact on that side. Hence the slip will be left plain. The spacing magnet, however, will be actuated as usual, and the plain slip will be drawn forward. The result is that the recorder slip is perforated in precisely the same manner as that passed through the transmitter at the sending end.

The reed is kept in vibration by the battery Y, and the circuit of the latter includes the contact B on the reed itself, and the contacts of the governing relay. Imagine the sending transmitter to be running without slip, or that slip punched with a long succession of Y R, Y R is being passed through it, so that

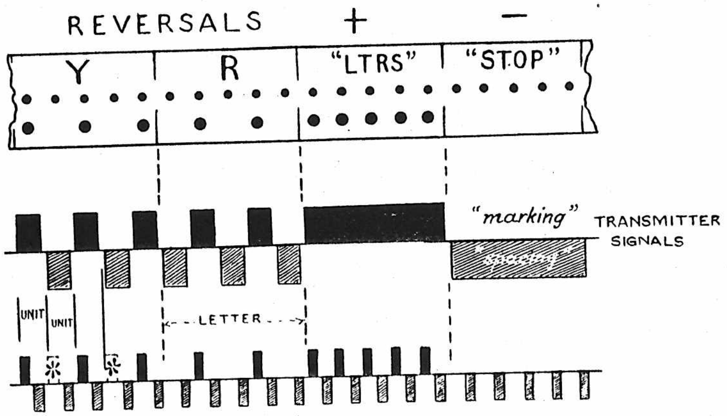


Fig. 139.

simple reversals are being sent out. The receiving relay tongue will follow these exactly, but the receiving reed must vibrate at *twice* this rate. This perhaps is better seen if we imagine that a string of "letter" blanks is being received. These form a continuous marking current, but taking each unit or perforation of the tape it will be seen that, for each unit, the receiving reed must make a marking and a spacing contact. This is illustrated in Fig. 139. The upper row represents a piece of slip punched with the letters Y, R, "letter" blank and "stop" (page) signal. The middle row indicates the movements of the transmitter contact lever, the full black portions above the line being the marking, and the shaded portions below the line the spacing

impulses. The lowest row represents the *effective* movements or contacts of the receiving reed: the black indicating the movement of the punching, and the shaded portions the movement of the spacing magnets respectively.

Thus with the first unit of current sent out (marking) the reed has to make a punching contact and a spacing one. The next unit is spacing, hence the punching circuit is incomplete, so that this impulse of the reed is ineffective, or its result suppressed as indicated by the asterisk, and so on. When the signal "letters" is received, the punching relay is permanently energised, and the punch is actuated with every contact of the reed on that side. With the "stop" signal, all the punching contacts of the reed are ineffective. This signal is utilised to break a contact on the recorder, and thus disconnect the spacing magnet circuit, and stop the feeding forward of the unpunched slip. On recommencing, several "space" signals are invariably punched, and these serve to re-start the recorder. A press button is also provided by which the punching magnet may be actuated by the receiving operator after a stoppage, and thus start the recorder again.

Governing.—The receiving reed is driven by its battery Y, whose circuit also includes the contacts of the governing relay. The armature of the latter moves every time the current is reversed. It is easily seen that if the movement of this armature (when it occurs) does not coincide with the movement of the reed, the time of duration of the contact with B will be shortened, and the pull of the reed magnet will be reduced. Under these conditions the buffer-springs tend to imprison the reed or to slow down its movements. This is the function of the governing relay, to cause the vibrations of the reed to take place in perfect accord with the movements of the receiving relay tongue.

Printer.—The upper portion of this is simply an ordinary typewriter, the depression of whose keys causes the required letters to strike the paper. Beneath the typewriter proper is the apparatus for automatically actuating the keys, when the received slip is passed through it. Figs. 140 and 141 give a front and back view of the instrument, and Figs. 142 and 143 illustrate the mechanism. The instrument shown is a hand-driven one, but a motor is now employed for driving.

Considering Fig. 142, X is one of the typewriter keys (as seen

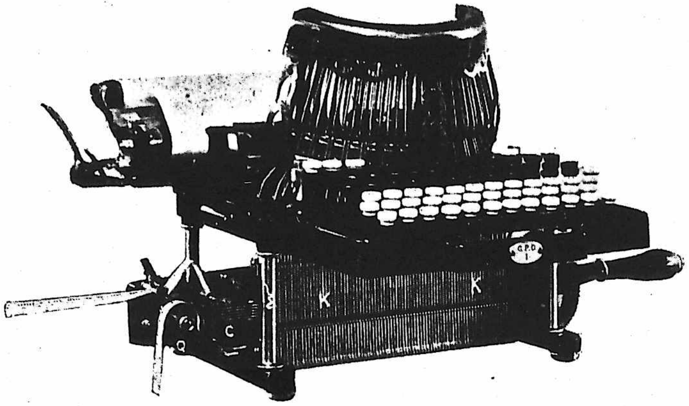


Fig. 140.—Murray printer: front.

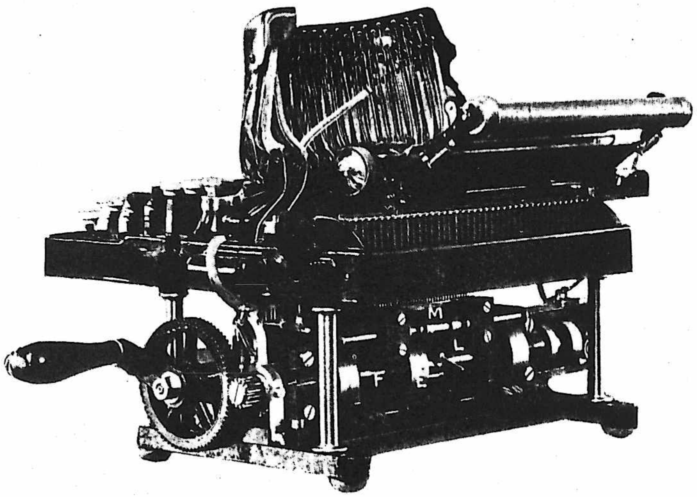


Fig. 141.—Murray printer: back.

from the side), the depression of which actuates the required letter by means of Z. On the under side of the key is a projection, Y, from which is pivoted a hook, H. Immediately in front of this hook is a strip, K, pivoted at A, and by means of a crutch at its upper end embracing the hook. The latter is kept in the crutch of K by a spiral spring, whilst a stronger spring, S, keeps K butting against the bar B. Every key of the typewriter is similarily furnished with a hook, H, and a strip, K. Behind the series of strips is the universal bar B, and six other bars or "combs" C. The latter, under certain conditions, will allow the strip K to move backwards if, at the same time, the bar B be drawn backwards also. The striking-bar J is carried by three arms M on the axle N, and is moved up and down by the shorter arm L. The latter travels in an eccentric groove in the disc E which is mounted on the shaft F.

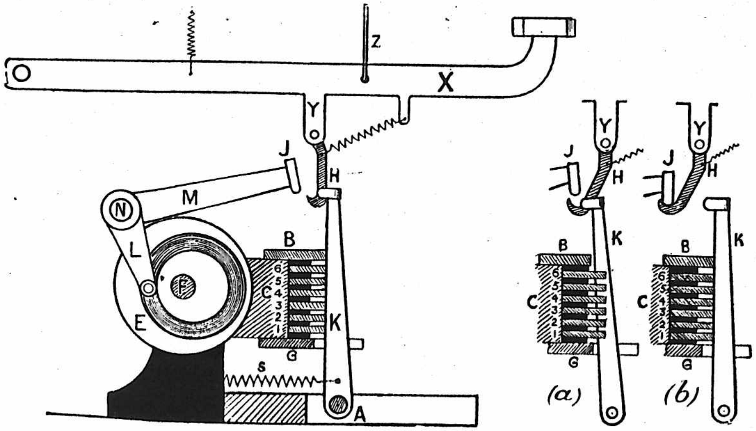


Fig. 142.—Printer: details.

When the six combs C are so arranged as to allow the strip K to move backwards, the universal bar is withdrawn and this movement of K takes place. In its movement it pushes H towards J as shown at (*a*) in Fig. 142. The striking bar descends and engages with the hook. The bar B then resumes its old position, restoring K and leaving the hook H engaged with J, as at (*b*) in the same figure. J then descends and pulls down the key. Having done this, J rises and the hook is drawn back into the crutched end of K by its spiral spring.

We now come to Fig. 143. Five of the strips K are shown with the projections Y from five keys, as seen from the front. The bar B and six combs C are seen running right and left behind the vertical strips. The five lower combs are provided with pointed ends on the left whilst the sixth is not so provided. For the present we shall consider only the five pointed combs, one of which is shown in the lower part of the figure (on a much smaller scale). From the latter it will be seen that the front edge, which is presented towards the strip K, is full of notches or is irregularly toothed. Now if all the combs were notched regularly and alike, so that a continuous vertical notch or slot existed behind each of the strips K, then on the withdrawal of the universal bar all the strips would move backwards and all the keys of the typewriter would be actuated. The notching, however, is irregular and each comb is notched differently to the others, so that with all the combs in their normal position (as in Fig. 143) there is not a single continuous slot. The withdrawal of the bar B under these conditions would have no effect, all the strips remaining unmoved.

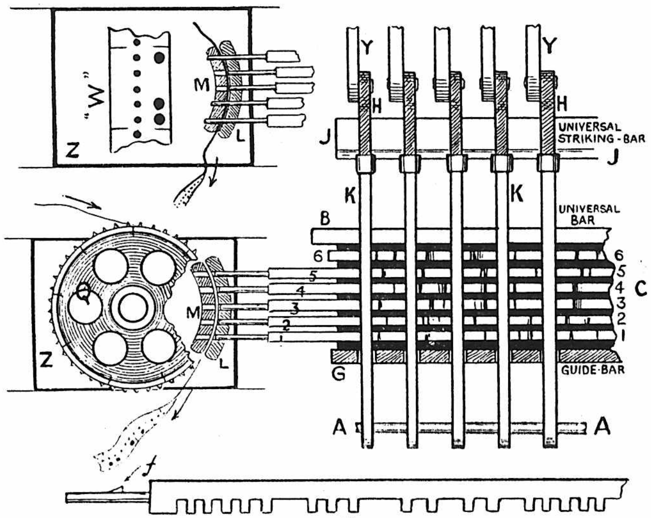


Fig. 143.—Printer: details.

But each comb is capable of sliding to the right by about $\frac{1}{16}$ inch, and the effect of such movement is to cause a continuous slot to be formed behind one of the strips. Imagine combs 1, 2, 3, and 4 to have a notch in each, exactly opposite, so that the notch is continuous across the four, but that No. 5 is unnotched in this region. Obviously the latter prevents the movement of its corresponding strip. If, however, the movement to the right of the fifth comb brings a notch in line with that in the others, the slot will be continuous, and on the withdrawal of B the strip will enter the slot and the corresponding key will be pulled down. This movement of the combs is brought about by the perforated slip. Each, as we have seen, is provided with a pointed end. To the left of these ends is a star-wheel, Q, round which the slip passes. Immediately opposite the combs is a guide, L, in which the pointed ends normally rest. Behind L is another guide M in exact alignment with it. The front of M is of the same radius as the star-wheel, and the faces of the two are arranged so that when the slip is brought between M and L by the movement of Q, the lower perforations are in line with the holes in the two guides whilst the central perforations engage with the projecting teeth of the star-wheel. Q and the other parts are mounted on a little carriage, Z, which is moved towards the combs and then withdrawn—both movements being effected by a cam on the shaft F (Fig. 142).

If now the carriage moves to the right—no slip being on the wheel—the pointed ends of all the combs enter the guide M, or rather the latter slides over the ends and no displacement of the combs occurs. But suppose slip to be inserted punched with the letter "W." As the carriage moves to the right the first, second, and fifth combs enter M, as the slip is perforated in the line of these guide-holes. As the slip is continuous in the region of the third and fourth combs these cannot pass through to M, but are pushed over to the right, as shown in the upper left-hand corner of Fig. 143. This arranges a continuous slot behind the strip K of the required letter, and on the withdrawal of the universal bar the strip falls and the letter is printed. The carriage moves back to its normal position and in its journey restores the combs to their old position by means of the little projection *f* on the pointed end (Fig. 143).

In every revolution of the shaft F we have the following:—The carriage Z moves to the right, setting the combs and opening a slot for the required letter; B is withdrawn, K moves backward, carrying H; the striking bar engages with H; B restores the strip K; J pulls down the key and then releases the hook H; the carriage returns, re-sets combs in alignment, and moves slip forward.

Letters and Figures.—The 5-unit alphabet, as we have noticed, gives us 29 signs or combinations. But these are practically exhausted in representing the alphabet alone. The same signs are, therefore, used for figures, &c., also, by prefixing a "letter" or a "figure" signal. This is the office of the sixth comb, of which we have not yet treated. This is notched in such a way as to permit of the making of the combinations we have just considered. That is, wherever a slot is made continuous across the five combs for a particular letter, the sixth comb is also notched, so that its co-operation is not required. If, however, the signal "figures" is punched, one of the strips K moves backward as usual. The strip does not actuate a key, but pushes the sixth comb slightly to the right by a wedging action. This has the effect of barring all the previous possible slots, and opening up a fresh set in the region of the figure keys. Any combination on the slip will now cause figures, &c., instead of letters, to be printed. When the signal "letters" is punched, another strip is actuated which pushes the sixth comb back to the left, thus barring the figure series and re-opening the letter series.

In other words, the notching on the five combs is such that a certain combination—say "W"—causes *two* continuous slots to appear in the five combs, one behind the strip which actuates the letter "W," and the other behind the strip actuating the figure "2." With the sixth comb in the "letters" position, however, a notch occurs in it in line with the letter "W," and an unnotched portion in line with "2." Hence the letter is actuated. With the sixth comb in the "figures" position the notched and unnotched portions are reversed, and the figure is printed.

The function of the "space" signal is simply to actuate the spacing key of the printer, and is unaffected by the position of the sixth comb. The "line" signal actuates special mechanism in the printer by which the printing is temporarily stopped and

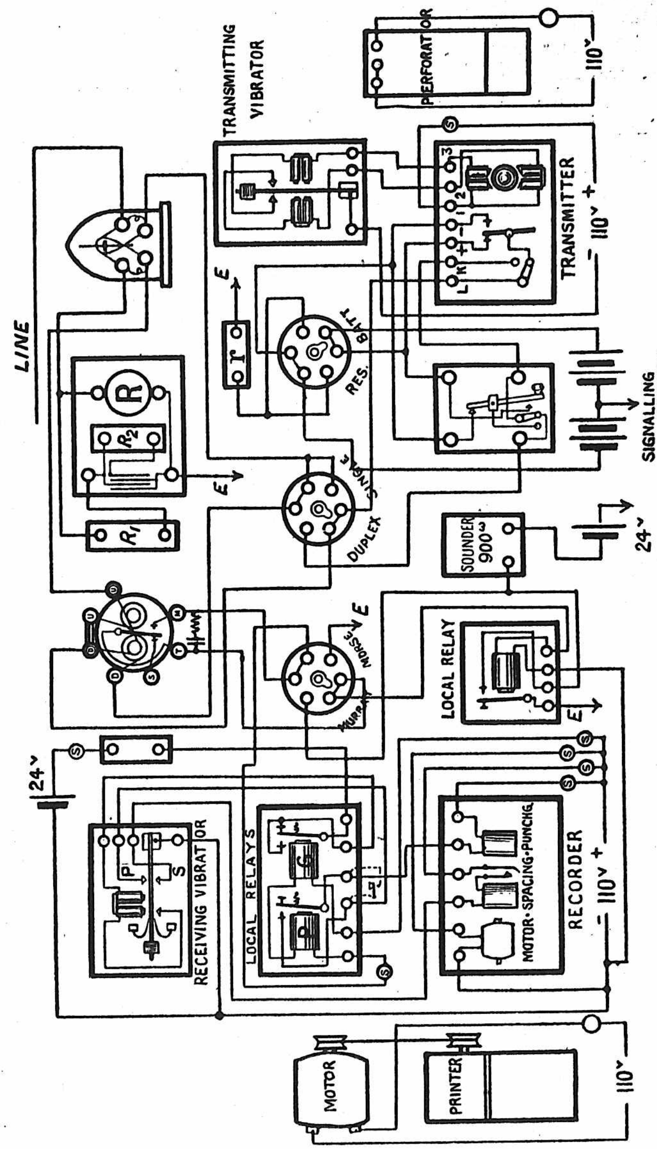


Fig. 144.—Diagram of Murray system.

the typewriter carriage run back so as to start a fresh line. This done, the printing re-commences.

Duplexing.—We have hitherto considered working one way only—*i.e.*, with the sending apparatus at one station and the receiving at the other. The system, as will readily be seen, is not adapted for alternate sending and receiving; if, therefore, one wire only is in use, duplex working is essential. This is accomplished on the differential plan, the transmitter sending to the split of a differentially-wound relay. The diagram of connections is given in Fig. 144. A Morse key and sounder are added to the equipment for speaking and balancing purposes, a switch bringing either the Murray or the Morse into use at will. In the former position a third local relay is in series with the punching and governing relays, and this actuates the sounder. The Murray signals are, therefore, constantly heard on the latter. When the switch is turned to Morse, the sounder only is worked by the line relay tongue.

CHAPTER X.

TEST AND BATTERY BOXES.

WHEN an office has but a single wire, and, consequently, but one instrument, the line is naturally brought direct to the latter. To disconnect or earth such a line the necessary arrangements must be made at the instrument itself. As soon, however, as the wires number more than two or three, it is obvious that such rough-and-ready means become impracticable, and a test board is introduced to which all the wires are brought, and from which the leads proceed to the respective instruments. All testing operations can then be performed at this board, and it forms a natural and easy means of distinguishing between instrument faults—or those in the office itself, for which the latter is responsible—and line or other faults outside the office and over which the station has no immediate control.

Similarly with the batteries. With one or two circuits the necessary cells are brought as near as possible to the instruments. At offices beyond this stage a separate room is demanded, which arrangement has the further advantage of rendering easier the operations of renewing, recharging, and maintenance generally. Hence the battery wires are conveniently brought to a battery box or board, where one set may easily be substituted for another, power increased, &c.

Screw-terminal Type of Board.—The oldest form of test and battery box alike is the screw-terminal pattern, illustrated in Fig. 145, and is the standard for stations having a comparatively small number of circuits. On a board of mahogany or teak is fitted a number of terminals, each of which is provided with a long shank which passes through the board, and has the connecting wire permanently soldered to it. For each line on which an instrument is placed four terminals are needed, but by combining those for two lines in one vertical row, seven terminals serve. The lines are brought to the uppermost and lowest terminals of such sets of seven, the middle one, which is blackened, serving as a common "earth," and the remaining two pairs are

> “I hear, I balance, I assess, but judge I do not.”
>
> *Ayesha.*

THE HISTORY OF THE TYPEWRITER:

Being an Illustrated
Account of the Origin,
Rise and Development
of the Writing Machine.

BY

GEO. CARL MARES.

THE
JOHN CRERAR
LIBRARY

1909
GUILBERT PITMAN
85, FLEET STREET, LONDON, E.C.

All rights reserved.

tank. Under the constant tension of the mainspring, the type-wheel tends to rotate in a constant direction, but is controlled by the escapement wheel, which is operated by the magnet. The escapement is so arranged that a single pulsation of the magnet causes the type-wheel to rotate through the space of two letters. Thus, if the type-wheel is to be rotated through the space of six letters, there will be three pulsations of the magnet, three teeth of the escapement being allowed to pass. When this has occurred, the wheel is brought up in its approximate position, or midway between any two letters, and it is now necessary to move the type-wheel to the right or left just half a space, or 1-72 of a revolution, in order to bring the desired letter to the exact position of printing.

The transverse motion of the type-wheel across the machine is accomplished by means of a cord which is attached at its centre to the type-wheel carriage, and extends parallel with the guide bar, passes over two small pulleys at the end of this bar, and is wound at each end on two drums. The drums are rotated by means of the ratchet wheel and the pawl at every pulsation of the magnet, each movement of the ratchet causing the type-wheel to travel transversely the space of one letter.

The printing done by this most ingenious little machine is remarkably even, and in its spacing and general typographical excellence it compares favourably with the best work that is turned out on the typewriter.

The Murray Telegraphic System. An exceedingly interesting method of telegraphic typewriting has been invented by Mr. Donald Murray, M.A., who uses as the base of his system the Bar-Lock typewriter. In the form in which it has reached its final development the method consists of a group of machines at each end of a telegraph wire. The message is perforated in a narrow paper tape, which is then run through an automatic transmitter, which, in its turn, sends signals over the wires corresponding to the holes in the paper tape.

These signals are transmitted over the line at a speed sufficiently high to permit the transmission of the messages punched by several operators over one telegraph line. At the receiving station an electrical perforating mechanism under the control of the transmitted signals makes an exact reproduction of the transmitting tape. This received tape then runs into the automatic typewriter or "printer," which prints the messages in ordinary typewriting in page form under the control of the perforated receiving tape, somewhat after the fashion of a mechanical piano. The speed of the printer is now very high, not less than 150 words (900 letters) a minute, but practical considerations of durability and maintenance of the typewriter, limit the speed at present to about 100 or 120 words a minute. The limit of speed in transmission of the signals over the line is in the receiving perforator which reproduces the tape at the distant station. With the improved machinery now in use, it has recently been found possible to punch the received tape faultlessly at the rate of 184 words (1,104 letters) per minute. At this speed no less than ninety-two holes per second have to be punched in the paper tape successively by a single punch. A similar group of machines in the reverse order are required for transmitting messages in the opposite direction on the same wire at the same time. It was a model of the printer, at that time in a very crude form, that Mr. Murray took to New York in 1899. In New York the electrical portion of the system for perforating the tape, transmitting the signals and perforating the received tape, was evolved. At that time the printer appeared to be a sort of combination of sewing machine and barrel organ. An operator had to work the printer by turning a handle, and the machine was variously known as "Murray's coffee mill," and "the Australian sausage machine," but more frequently as "the Baby." In London the printer was very greatly improved. An electric motor to drive it was provided, and all the actions were made automatic, the machine stopping at the end of each line, running the typewriter carriage back, turning up a new line, and starting again, and finally stopping at the end of each message, all under the control of the perforations in the paper tape. A very necessary improvement was a method of invisible correction of errors in the transmitting tape. With the system in its now perfected form, if an operator on one of the keyboard perforators at the sending station strikes a wrong key or perforates a wrong word, all he or she has to do is to press a back-spacing lever and a "rub-out" key once for each wrong letter. This action punches the erroneous portion of the tape full of holes so as to obliterate the wrong letter or letters. This obliteration is reproduced in the receiving tape at the distant station, but the printer is so arranged that it stops work for the moment during which the obliterated portion of the tape is passing through it. The result is that no trace of the error, not even a blank space, appears in the printed message.

The system has been in steady commercial use for about three years between London and Edinburgh, and a circuit is now being equipped with Murray apparatus between London and Dublin. For about eighteen months it has been working between Hamburg and Berlin. An installation has been set up between St. Petersburg and Moscow. An installation of the apparatus for Calcutta-Bombay (1,200 miles) is now approaching completion and arrangements are being made for a staff of Murray experts to go out to India to instal the system. A set is nearly finished for working between Vienna and Prague, and arrangements are also being made for manufacturing Murray apparatus to equip several other circuits.

It may be mentioned that Mr. Murray has been engaged by the British Post Office for a term of years to invent and develop some new printing telegraphs to suit special conditions. Mr. Murray points out that this engagement is in accordance with a tendency that has become very marked of recent years.

Creed's Telegraphic System. Mr. F. C. Creed, of Lenzie, in Scotland, has also invented, and is now perfecting a series of three machines having similar objects, and from an account of the system in a Glasgow paper we learn that, although other inventors have produced instruments which aim at results somewhat similar to those achieved by Mr. Creed's Perforator, Receiver and Printer, yet they labour under this disadvantage, that they deal with a perforating alphabet entirely different from the Morse, which is used in the Telegraph service of the United Kingdom. Mr. Creed has endeavoured to adapt his machines to the Morse alphabet, and has succeeded in doing so.

After many years of labour, Mr. Creed succeeded in producing the perforator, which is now being tested in London. It is operated by means of an ordinary typewriter keyboard. When the lettered keys are touched they perforate a corresponding Morse letter on the paper tape. The speed with which this is accomplished is about the same as that attained in ordinary typewriting, and as this is double the average speed of ordinary punching, the new perforator can perform the work of two punchers. The tape perforated after the new fashion may be put into the Wheatstone transmitter at the London end of the wire and received at the other end in the manner at

present vogue, or advantage can be taken of Mr. Creed's new receiver, which reproduced at the end of the wire a perforated instead of an inked tape, identical in all respects with that put into the transmitter at the London end. This machine is necessarily more complicated than the ordinary Wheatstone receiver, and does not work at such a high speed. At present a Wheatstone receiver can carry at the rate of—according to the condition of the wire—from 250 to 350 words a minute. But the maximum speed as yet attained on Mr. Creed's new receiver is a little over 150 words a minute. Then comes the third of the inventions. When the tape thus perforated passes through a machine which actuates an ordinary typewriter in accordance with the perforations which play the part of human fingers usually applied to the keys—something after the fashion of the Jacquard loom—and the perforated tape is turned into printed letters and words. No transcribing by hand is required. The typewriter is moved by means of a motor, and the "copy" is delivered in page printed forms. This has been accomplished on an experimental machine at the rate of seventy words per minute, but Mr. Creed expects to attain fully 100 words a minute, so that here the speed would be four times that of a longhand writer.

The Electrograph. A few words on this machine whereby pictures may be telegraphed may not be out of place in these pages. From a description written in 1902 by Mr. Donald Murray in *Everybody's Magazine*, we learn that the design or illustration to be transmitted is first of all reproduced as an ordinary half-tone illustration, of which many instances occur in these pages. The plate is then flooded with melted wax, and then rubbed to a smooth surface. This fills the depressed portions with an insulating material, leaving all other parts smooth and clean. The plate is then bent around the cylinder of the transmitting machine, the operator closes his key, and the electric current does the rest.

The distant receiving machines have plain white paper wrapped around their cylinders. The closing of the circuit by the transmitting operator starts all machines at once, and in six to ten minutes the picture is completed.

The automatic operation is really a very simple one, though the results are almost beyond belief. The transmitting stylus, a fine steel point, traces a spiral upon the zinc plate, while the wax dots, rapidly breaking the circuit,

Samuel Insull

3

JOURNAL

OF THE

INSTITUTION OF ELECTRICAL ENGINEERS,

ORIGINALLY

THE SOCIETY OF TELEGRAPH ENGINEERS.

FOUNDED 1871. INCORPORATED 1883.

COMMONWEALTH EDISON COMPANY
LIBRARY
CHICAGO

EDITED BY P. F. ROWELL, SECRETARY.

VOL. 47. 1911.

E. AND F. N. SPON, LIMITED, 57, HAYMARKET, LONDON, S.W.
SPON AND CHAMBERLAIN, 123, LIBERTY STREET, NEW YORK.
1911.

PRACTICAL ASPECTS OF PRINTING TELEGRAPHY.

By DONALD MURRAY, M.A., Member.

Paper first received January 17th; received in final form February 17, 1911. Read before the INSTITUTION *May* 4, 1911.)

In a paper read before the Institution in 1905,[*] under the title of "Setting Type by Telegraph," an outline was given for the first time of the theoretical aspects of printing telegraphy. The author has always had in view the preparation of a second paper dealing with printing telegraphy from a practical point of view, especially in regard to the obstacles that stand, or formerly stood, in the way of the general introduction of printing telegraphs. The subject does not appear to have been treated in any publication, and as it is probable that these obstacles will, in time, acquire historic interest for telegraph engineers, it seems desirable to have them put carefully and fully on record. During the past ten years the author has had unique experience of these difficulties in New York, Boston, London, Birmingham, Manchester, Edinburgh, Berlin, Hamburg, Vienna, Stockholm, Gothenburg, St. Petersburg, and Moscow, and the following paper embodies the results of that experience.

SUMMARY.

The paper is divided into three parts, as follows: Part I., dealing generally with the field for printing telegraphy; Part II., dealing with the practical difficulties in the way of printing telegraphy; Part III., describing some printing telegraph apparatus designed to overcome these difficulties.

PART I. discusses the field for printing telegraphy, and it is shown that there is little scope at present for printing telegraphs in wireless work, in railway telegraph traffic, or on long ocean cables. Their use is chiefly in connection with land telegraph lines between centres of population, and it is shown that printing telegraphs will, in the future, perform a very important service in assisting the co-operation between telegraph and telephone. It is admitted that for transmission of intelligence over short distances the telephone stands unrivalled; but it is contended that for the transmission of intelligence over considerable distances the most efficient arrangement is a combination of the telephone and telegraph, the telephone acting as the collector and distributor for long telegraph lines. The reason is that the cost of long telephone lines is very great, while the labour cost of a telephone conversation is extremely small and the time-saving is great. With the telegraph, on the other hand, the cost of the line is less than one-quarter of the cost of a telephone line; but the telegraph labour cost is very heavy and there is much loss of time. By co-operation between the telegraph and telephone the advantage of the cheap telegraph line is combined with the advantage of the low labour cost and time-saving of the telephone. It is therefore contended that economic necessity will in future lead to a great increase in telephone-telegrams, or, as the British Post Office already calls them, "phonograms." Printing telegraphs will form essential links in the telephone-telegraph network, because printing telegraphs are the only means by which the carrying capacity of telegraph lines can be greatly increased and the labour cost at the same time decreased.

PART II. is a long and detailed account of the difficulties that have been encountered in connection with the development and practical application of printing telegraphs. With the idea of forming an historical record of these difficulties, they have been fully and minutely described. It is pointed out in the first place that the saving of labour by the use of printing telegraphs cannot in the nature of things be very great; but that there is reasonable ground for expecting to save from 25 to 50 per cent. in labour compared with the Morse key and sounder. The obstacles encountered in dealing with both commercial and press messages are discussed.

The difficulties in the way of making a copy for record of telegrams delivered are explained, and it is pointed out that wet-press copying is the only practical method of retaining copies of telegraph messages when printing telegraphs are used. The necessity for keeping copies of telegrams at all is not quite obvious.

When page-printing telegraphs are used a change is necessary in the telegraph forms used by various Administrations. There are two kinds of telegraph messages, those sent from city A to be delivered in city B, and those sent from city A to be retransmitted in city B to city C. In city B nearly all telegraph administrations use two different kinds of telegraph forms to distinguish these two kinds of messages. For a page-printing telegraph only one form for both kinds of messages is possible.

Numbering telegraph messages presented some difficulties in England when the Murray automatic printing telegraph system was introduced.

Counting the number of words in telegrams is a serious burden. There are so many Siamese twin words that are neither one nor two, that counting words is difficult, and the necessity for careful checking and counting considerably diminishes the number of telegrams that it is possible to transmit per hour. It also increases the labour cost. If it were possible to charge for telegrams in some way by time as

---

[*] *Journal of the Institution of Electrical Engineers*, vol. 34, p. 555, 1905

in the case of the telephone, instead of by words, a lot of delay and labour would be saved.

Errors in telegrams, due to the telegraph line, to the telegraph machinery, and to the human operator impose very serious limitations on the time and labour saving possible with printing telegraphs.

The variety of telegraph messages and the irregularity in the flow of telegraph traffic also greatly reduce the possible time and labour saving.

Traffic arrangements and hours of duty of operators are necessarily of a very complicated character in the case of large telegraph administrations, and the introduction of printing telegraphs leads to considerable variation of these arrangements. It is most difficult to introduce changes in the daily routine of large numbers of human beings. Of course, in the case of France, Germany, and other countries on the Continent of Europe, where the Hughes has been largely employed for more than a quarter of a century, such difficulties have long since adjusted themselves. It is in the Morse key and sounder countries that the introduction of printing telegraphs necessitates some changes of routine.

International telegraph traffic presents special difficulties because of the division of authority and differences in habits and ideas and customs and differences in language.

Alphabetical troubles are not the least that printing telegraph inventors have to encounter. Each country requires some variation in the telegraphic alphabet, and it appears to be a physical impossibility to devise a printing telegraph that will suit all languages. A curious illustration of this alphabetical difficulty is the confusion that exists in Great Britain through the use of the oblique stroke both for money and fractions. 3/8 may be read as 3s. 8d. or as $\frac{3}{8}$. This confusion has led to monetary loss.

Code and cipher messages are the despair of telegraph administrations, but on the whole a good printing telegraph can handle such messages with less risk of error than the Morse key and sounder, and at least as expeditiously if proper methods are used. The essential condition is careful training of operators in working on typewriter keyboards without looking at the keys.

The use of envelopes and the addressing of telegrams present difficulties in the case of page-printing telegraphs. On the Continent of Europe envelopes are not used, and the telegrams have to be folded up in special ways varying with each administration. The printing of the messages must suit these methods of folding. This requirement is hard to fulfil in the case of a page-printing telegraph.

Finally, there are mechanical difficulties of construction. Printing telegraph machines belong to a theoretically bad group of mechanisms, in which the majority of the actions are striking instead of sliding or rolling, and it is only by close attention to details that success has been achieved.

Part III. gives a brief general description of the Murray automatic system and a more extended description of the new Murray multiplex system as an illustration of some methods by which it has been attempted to save time, line, and labour in telegraphy and to overcome the difficulties enumerated in Part II.

PART I.

INTRODUCTION.

For any distance exceeding a few miles, our sole physical means of transmitting intelligence at a speed greater than by letter post is the electric wave. There are only two possible methods of using the electric wave for signalling—namely, the guided wave along a wire (ordinary telegraph and telephone) and the unguided wave (light signals and "wireless"). Electric waves in the form of light have so many limitations that they are of no importance from the printing telegraph point of view, except as a local means of printing, and further reference to them in this paper is not required. As the longer waves used in wireless telegraphy have a much greater range on the surface of the earth, no doubt in time wireless printing telegraphy will receive more or less attention, but it will not be of much importance, in this generation at any rate, because there cannot be any saving of line or line maintenance when there is no line. Any saving of labour that might be effected by wireless printing telegraphy is of trifling importance, because the wireless operator has to be in attendance in any case, and the speed of signalling is low. It is in supermarine telegraphy, where it is impossible to use the guided electric wave, that wireless telegraphy has its great field, and in nearly all cases of ship telegraphy the work can be dealt with easily by one operator. Also the Morse key is the quickest means of communication (excepting the telephone). Hence in most wireless work, printing telegraphy would save neither line, labour, nor time. There is nothing else that it can save. Under such circumstances the extra cost and complexity of printing telegraphs would not be justified. Possibly for rapid transmission of wireless messages between two fixed centres, printing telegraphs may come into use, but not in the immediate future. Wireless printing telegraphy therefore does not require consideration, and we may confine ourselves to the guided electric wave as used with the telephone and telegraph, including underground and submarine cables. Transmission of intelligence so far as the guided electric wave is concerned may be classified into short-distance and long-distance telephone traffic and short-distance and long-distance telegraph traffic. Further subdivisions of telegraph work, which overlap more or less, are land traffic, cable traffic, news work, commercial and other ordinary short telegrams, railway work, and the stock ticker and urban news service.

It is not necessary in this paper to touch on the local transmission of intelligence over distances more or less within city limits. For this purpose the telephone and stock-ticker and telautograph have reached a high state of development and form a group by themselves. The difficulties they have had to face have been almost entirely mechanical. No serious obstacles have been presented by the nature of the traffic they have to deal with. Hence they will only concern us in so far as they serve as feeders to the general telegraph and telephone network between centres of population.

For railway work printing telegraphs have hardly been employed at all up to the present, and as the telephone is gradually displacing the telegraph for most railway work in America, and therefore no doubt in time in other countries also, printing telegraphy does not appear to have any extensive possibilities in conjunction with railways, and it therefore does not require special discussion at present. In time, printing telegraphy will probably play a considerable part in connection with ocean cables, but up to the present hardly anything has been done in this direction, because the conditions to be fulfilled are extremely complicated. In the first place, there cannot at present be any line saving, because ocean cables are already utilised up to their full capacity. It will be possible to effect a slight saving of time and some saving of labour, but the apparatus will necessarily be of a very delicate and intricate character. The expenditure will necessarily be heavy, and the saving will not be more than about £300 or £400 a year on each cable, at each end. The saving of time is more important on the Atlantic cables, and reliable apparatus that would print messages in Roman type direct from the cable signals would be attractive to the cable companies in places like New York, where the cables terminate in Wall Street, the business heart of the city. Meanwhile the attention of printing telegraph inventors is absorbed by land line work, and printing telegraphs for ocean cables have to wait. The application of printing telegraphs to news work will be dealt with later on.

So far as the present position of printing telegraphs is concerned, the Hughes tape printer carries the bulk of the telegraph traffic on the Continent of Europe, and it has done so for nearly half a century, about 3,000 Hughes instruments being now in use. Most of the telegraph traffic between Great Britain and the Continent is also carried by the Hughes, but this machine is only employed outside of Europe to a very slight extent. During the past thirty years the Baudot system, which may be described as a multiplied Hughes tape printer, has been developed and extended in France until all the telegraph lines of any importance are equipped with it. During recent years it has also made considerable progress in Italy, Brazil, India, and Russia. In Russia it is quite extensively used, most of the leading towns in European Russia being connected by it. It has likewise secured some foothold in most other European countries, Paris being linked up by it to nearly all the capitals of Europe.

Great Britain has proceeded in very leisurely fashion, and, so far, has only coquetted with printing telegraphy, more or less prolonged flirtations having been carried on by the British Post Office with the Hughes and Baudot, the Buckingham, the Murray automatic, the Siemens and Halske, and several other systems. The latest arrival, the Murray multiplex, may be described as the child of the British Post Office, it having been developed with the assistance of that Institution. The Murray automatic system has made most progress up to the present in Germany. It has also secured a foothold in Russia, Sweden, and Norway. It is in regular commercial use between Hamburg and Berlin, Berlin and Frankfurt, Hamburg and Frankfurt, Berlin and St. Petersburg, St. Petersburg and Omsk in Siberia (about 2,400 miles with three repeating stations), Stockholm and Gothenburg, Kristiania and Bergen. A new installation with all the latest improvements is being established between London and Dublin. For various reasons, however, the use of the Murray automatic system is limited to long lines and underground cables, and there is consequently not a very wide field for it, especially in comparatively small countries like Great Britain. The Murray multiplex, on the other hand, is very well adapted for moderate distances, but it has not yet had time to come into extensive use. In the United States the Buckingham system was developed under the auspices of the Western Union Telegraph Company, and some 60 circuits are now equipped with the Buckingham system as improved by Barclay.

Printing telegraph inventors are still busy increasing the height of the printing telegraph scrap pile, as they have been doing for fifty years, especially in America, but the substantial results over the whole wide world are summarised in the foregoing paragraphs. These results are neither extensive nor brilliant, and it is an actual fact that less than £1,000,000 sterling would cover the value of all the printing telegraph machinery on the face of the earth to-day. This is the outcome of fifty years of constant labour by scores of inventors. We have only to compare this with the gigantic extension of telephone apparatus all over the world in only a few years to realise that there must be some hampering circumstances, some peculiar difficulties and obstacles in the way of printing telegraphy, when we compare its stunted growth with the enormous progress of the sister art of telephony. It is the intention in this paper to give a full and detailed account of these peculiar obstacles and difficulties, and of the exceedingly complicated conditions with which printing telegraph systems have to comply.

For this purpose it is necessary first to get a clear, general view of the practical processes employed in the transmission of intelligence by the telephone and by the telegraph. In doing so we have to bear in mind that in the transmission of intelligence there are four economies of fundamental importance, namely :—

1. To save time.
2. To save labour.
3. To save line.
4. To save office equipment.

Everything turns on these four vital points. They are all more or less antagonistic economies. Time, for instance, can be saved by increasing labour cost or *vice versâ*. Good management is a question of balancing these economies against each other so as to secure the maximum result. Investigation shows that it is far more important to save time, labour, and line than to save office equipment. Heavy expenditure on office equipment in the shape of printing telegraph machinery is therefore one of the inevitable developments of the future. As will be seen presently also, the necessity for co-operation between the telegraph and telephone will compel development in the same direction. That the relation of the telephone to the telegraph has an important bearing in regard to printing telegraphs will be seen from the following considerations: In the case of the telephone the sender and receiver of a message are put in direct communication, and there is no intermediate labour whatever. This result, however, is only obtained over anything more than moderate distances by heavy expenditure on telephone lines. Two expensive copper wires are needed for the telephone in place of one cheap iron wire for the telegraph. The telephone line expenditure, in fact, is so heavy for long distances that beyond about 1,000 miles the cost becomes almost prohibitive. The theoretical reasons for the great differences between telegraphic and telephonic methods were given in the paper on "Setting Type by Telegraph," already referred to,* and it is only necessary here to deal with the practical aspects of the matter. In the case of the telephone there is no scope for machinery, so far as the actual transmission of the message is concerned, because there is no labour at all beyond speaking and listening. The cost of a telephone message over a short distance is therefore very small—2d. for about 200 words sent and 200 received in reply—and there is absolutely no delay or loss of time except in getting connected. Obviously the telephone saves enormously in time and labour, that is to say, in two out of the four vital elements of cost. It is this enormous economy that has led to the expenditure of such immense masses of capital in the extension of the telephone service all over the world. In the case of the telegraph the conditions are almost exactly opposite, and the telegraph at present is more or less crushed between the upper and nether millstones of the telephone and the letter post. It is only over long distances that the telegraph stands supreme, and it does so because of the very low cost of the telegraph line compared with the telephone line. The relative value of the telegraph increases and the relative value of the telephone decreases rapidly in proportion to the distance.

Let us take the case of a business man in London who wants to communicate with a man in Birmingham, a short distance of about 120 miles. If he telephones he gets direct communication in a few minutes and at no great cost. (There is, of course, often considerable delay in getting a trunk connection, but it is much less than the delay in getting a reply by telegram.) If he telegraphs he has first to dictate the telegram to a clerk, who writes it out and hands it to a messenger-boy, who takes it to the nearest telegraph office and hands it to a counter-clerk, who counts the number of words and collects payment. A messenger then takes it and puts it in a pneumatic tube, by which it goes to the London central telegraph office. Here a messenger takes it out of the tube and it goes to a table sorting clerk, then to a messenger, who again puts it in a pneumatic tube to one of the telegraph galleries (operating halls). Again in the gallery it goes through the hands of a sorting clerk, and then a distributor takes it to the circuit box, where it is dealt with by the traffic clerk of the circuit. An operator then telegraphs it over the line to Birmingham, where it is received by another telegraph operator. It is taken away by a collector to a delivery officer to be enveloped and addressed. Then finally a messenger takes it to the addressee. In the case of messages passing from city A through city B to city C the human chain is still further extended, but taking the foregoing as a fair average journey for a telegram, we see that between the sender and receiver of the message there are no less than 15 middlemen. In the case of long-distance messages this chain of middlemen may easily extend to 20 or 30. Not only is there heavy labour cost, but also much time is lost in this elaborate process. The result is that not only does an average telegram take an hour or more to reach its destination, but the excessive labour employed in handling it makes it very costly. Instead of 2d. for about 400 words, a telegram costs 6d. for 12 words—that is to say, 1d. for 2 words instead of 1d. for 200 as in the case of the telephone.

The vital importance of printing telegraphs lies in the fact that they can greatly reduce the present waste of line and labour in telegraphy, and that they render it possible to foster the growing co-operation between the telegraph and the telephone. The telegraph and telephone are each strong where the other is weak. We can set out the points in tabular form thus:—

	Telegraph.	Telephone.	Telegraph-telephone.
Time	Wasteful	Extremely economical...	Fairly economical.
Labour	Wasteful	Extremely economical...	Fairly economical.
Line	Very economical...	Very wasteful	Very economical.
Office equipment ...	Cheap	Expensive	Expensive.

If we utilise the telephone as the short-line feeder and distributor for the long-line telegraph we get the ideal co-operation shown in the last column of the table. The cost of office equipment will be increased, but this will be outweighed ten or twenty fold by the economies of line, labour, and time.

If telegraph messages were charged for like telephone messages, by time instead of by the number of words, a lot of the labour cost would fall away. A merchant would then ring up the nearest telegraph office. He would be switched on to the required circuit, and he would dictate his message direct to a telegraph operator, who would type it on a rapid keyboard tape perforator. The perforated message would run through an automatic transmitter, and would be printed automatically direct from the line signals at the distant station, from which point it would be telephoned at once to the addressee. In this way the elaborate telegraph labour chain would be reduced from 12 or 15 to about 4, with corresponding reduction in the cost and saving of time. This may be an impossible ideal, but there is no reason why there should not be some approximation to it. Indeed, this telephone-telegram idea is already slowly emerging into everyday use. The British and other administrations now accept and deliver telegrams by telephone, and the British Post Office has actually coined the special name of "phonograms" for such telephone-telegrams. As telegrams can already be sent to or from a telegraph office by telephone, it is only a question of time for several more links in the long telegraph labour chain to be cut out, and *messages will be sent by telephone direct to the particular telegraph circuit over which they are to be transmitted.* There will be no more difficulty about that than there is in handling trunk telephone calls. It will be noticed, however, that the success of such an arrangement is conditional upon the rapid handling and transmission of the messages. If a merchant wished to dictate a message over the telephone direct to a telegraph operator on a particular circuit, and if he had not only to wait his turn, but also to dictate at the crawling manual speed of the Morse key and the operator writing at the other end of the telegraph line, the arrangement would never come into popular favour. The message should be recorded as perforated paper tape from dictation over the telephone at a speed of at least 60 words a minute, or it should be recorded at this speed or more on a typewriter at the circuit over which it is to be transmitted. Also the best the slow Morse key can do is to give two simultaneous transmissions in one direction on one telegraph wire. To handle "phonograms" under ideal conditions there should be a system giving either high automatic speed of transmission or at least four simultaneous transmissions in each direction on busy lines, and the speed of each transmission should be a steady average of at least 40 words a minute.

---

* *Journal of the Institution of Electrical Engineers*, vol. 24, p. 555, 1905.

Not only would quick handling and transmission of messages be necessary, but also quick reception and printing of the messages at the other end of the line ready for transmission by telephone. Printing telegraphs are a necessity for such methods of handling telegrams. Even in the case of the general public, who would continue to hand in their telegrams in the usual way at telegraph offices, much time and labour would be saved if the messages could be sent by telephone from the local telegraph office direct to the trunk telegraph line and recorded on a keyboard perforator in the form of perforated paper tape, ready for automatic transmission. The chief stumbling-block at present in the way of this arrangement is the practice of charging for telegrams according to the number of words. An incredible amount of time and labour is wasted in counting the number of words in telegrams. The telephone prospers without counting and recounting words. The telephone does not reckon "three-halfpence" as one word and "three hundred" as two words, to say nothing of other telegraphic word-counting absurdities. A rational system of charging for telegrams is badly needed, but it is difficult to imagine what plan could be substituted for the present clumsy but practical arrangement.

In addition to the telephone as a local collector and distributor of telegrams, there appears to be a field for the small step-by-step printing telegraphs generally known as stock-tickers. The Siemens and Halske teletyper is a good example of this class of machine. From a technical point of view it is an admirable little instrument, and on the Continent of Europe it is being exploited commercially with considerable vigour and success. It is quite largely in use in Germany, Berlin and several other leading German cities having ticker exchanges in connection with the head telegraph offices arranged somewhat on the lines of a telephone exchange. Any subscriber can send telegrams to the head telegraph office or receive them by means of the teletyper. By having one or two of these little instruments at each important circuit, and by having suitable switching arrangements in the exchange, subscribers could send in their messages direct to any required circuit or receive them direct from any circuit in the same way. The advantage of this arrangement would be that there would be a printed record of the message in the office of the sender and also in the head telegraph office, and it is probable that there would be less liability to mistakes than in the case of the telephone. These little machines, however, are more expensive and complicated and slower than telephones, and in the nature of things can only come into very limited competition with the telephone. The same remarks apply to the telewriter. This will also, no doubt, prove useful in collecting and distributing telegrams locally, but it is the telephone that will in time do the bulk of the local collection and distribution of messages sent over telegraph lines.

Meanwhile we have to see what steps we can take to reduce labour cost of telegrams under present conditions. The line cost also is important, but nothing like so important as in the case of the telephone, and, except in the case of very long lines, it is not so important as the labour cost. On the other hand, we have the letter post, by which we may send 5,000 or more words for one penny. The time of transmission is a good deal greater than in telegraphing over long distances, but there the advantage of the telegraph ends. Why spend sixpence on a telegram when you can telephone for twopence or send a letter for a penny or a postcard for a halfpenny? The answer is, that you cannot telephone for twopence except over short distances, and that letters take a long time to go long distances and telegrams do not. The telegram is the cheapest quick method of communication over considerable distances. The subject is very complicated and there are many obstacles, but threepenny telegrams and quick service would lead to a wonderful growth of telegraph traffic. Threepenny telegrams and quick service depend on rational co-operation between the telegraph and telephone, upon the extension of the telephone to practically every office and home, and last, but not least, upon efficient printing telegraphs. It is a more or less instinctive appreciation of these facts that has led the British and other telegraph administrations to experiment so extensively during the past few years with various new printing telegraph systems. Much yet remains to be done, but it is practically certain that in the course of the next 10 or 15 years the British Post Office alone, to say nothing of other administrations, will have to spend not less than a quarter of a million sterling on printing and other telegraph machinery in telegraph offices—that is to say, on "office equipment." There are, of course, many other relative advantages and disadvantages of the telephone, telegraph, and letter post, but it is not necessary to discuss them here, as they have no special bearing on printing telegraphs.

PART II.

DIFFICULTIES IN GENERAL.

The printing telegraph inventor has to dance in chains, which are none the less heavy because they are invisible. He has to conform to most intricate and unexpected conditions, and although the telegraph administrations are benevolently disposed, and do all they can, in the public interest, to assist in the development of printing telegraphy, they are still bound to look at the matter from the financial point of view, and to insist on a printing telegraph showing either (1) a saving of labour, or (2) a saving of line, or (3) a saving of time in transmission, or if possible all three. In fact, we may say that the difficulties in the way of introducing printing telegraphs are essentially commercial. The employment of printing telegraphs involves a considerable increase in the cost of office equipment, and there must be a substantial justification for that expenditure in the shape of saving in line, labour, or time. The most attractive feature in the eyes of the majority of telegraph administrations is the saving of labour, and the saving of labour by means of a printing telegraph is a peculiarly intricate problem. Time and labour saving in telegraphy are often antagonistic, and in this case we have to face one of the maximum problems, of which there are so many in our modern civilisation. We have to calculate and balance out the gains and losses of time and labour so as to get the maximum benefit.

As a practical illustration we may take the question of automatic tape transmission of signals *versus* direct transmission. This happens to be one of the most important of these maximum problems—these compromises between time, labour, and line saving. At the first glance direct transmission seems to be the best, and most printing telegraph inventors have adopted this plan, but it is not the most economical, and it is not necessarily the quickest. Take the case first of direct transmission on a keyboard limited to, say, 40 words a minute. The operator's maximum speed is limited to 40 words a minute, and his average will certainly not be more than 30, apart from any stoppages to decipher badly written messages, to pick up and lay aside messages, and to sign and time them. All these delays on the part of the operator mean loss of time on the line and diminished carrying capacity for traffic, unless a second operator is assisting him so that he may send continuously. This plan, however, means waste of labour. On the other hand, with automatic perforated tape transmission on a transmitter running at 40 words a minute there are none of these delays. Transmission is continuous, and the operator working on a keyboard perforator finds no limit to his speed of operation. His short stoppages do not stop transmission, which is continuous. Actual trials on the Murray multiplex at 40 words a minute show that an operator can do double as much work with automatic tape transmission as with direct transmission. Not only is there 100 per cent. increase in the efficiency of the labour, but there is corresponding increase in the carrying capacity of the line. Also, although it may be said that there is a minute or so extra delay in perforating a message before transmission, and that therefore direct transmission saves time, this is not the case if there is pressure of traffic, because automatic tape transmission, by increasing the efficiency of the operator and the carrying capacity of the line, clears off traffic more quickly and reduces any tendency for messages to accumulate.

The only alternative in the case of direct transmission keyboards is to speed up the machinery from, say, 40 words a minute to, say, 80 words a minute. In this case the speed of the keyboard is above the maximum speed of the average operator, and it is practically free, like a typewriter keyboard. In this case, therefore, the operator can deal with as much work as on a keyboard perforator for automatic tape transmission, but this advantage is only obtained by a great sacrifice of line-carrying capacity. One operator cannot average by the hour more than about 30 words a minute, so that the line is used at 80-word speed for a 30-word output. With automatic tape the 80-word speed would give two simultaneous transmissions of 40 words a minute each, and the carrying capacity of the line would be doubled. On circuits where the traffic is not heavy, and where the carrying capacity of the line is much above requirements, the speeding up of the direct transmitter is a practical plan, and will come into use on such lines, but not on lines where there is heavy traffic.

One of the fundamental features of telegraphy is that a very large proportion of the total work must be performed by the human hand and mind. It can never reach the condition of a modern flourmill, where grain goes in at one end and flour comes out at the other with a minimum of labour. Telegraph messages cannot be made to flow along automatically in a steady stream under the watchful eye of a few supervisors. On the other hand, suitable printing telegraph machinery and the assistance of the telephone can greatly reduce the amount of labour at present required for handling telegrams. In small countries with dense populations like England, France, and Germany, time and labour saving are the most important points. In Europe the distances within each country are, in most cases, comparatively short, and the differences of language reduce the number of long-distance messages to a small fraction compared, for instance, with the long-distance traffic in the United States, especially when it is remembered that the United States has only a population of 90 millions and Europe has over 300 millions. If Europe was a united one-language country the long-distance telegraph traffic would be enormous, and the printing telegraph problem in Europe would take on a very different aspect from what it has at present. Many difficulties that are now almost insurmountable would disappear. On the other hand, the telegraph traffic within each European State over comparatively short distances is often very heavy. Conditions in Europe are, therefore, different from the conditions in the large new countries. In Europe, excluding Russia, labour saving is most important, especially as the telephone has cut into telegraph traffic to such an extent that during the past few years the growth of telegraph traffic in most European countries has been small or nil. In Great Britain underground cables have increased the superfluity of telegraph wires for the time being. Hence Western European administrations have enough telegraph lines in most cases, and means of increasing the carrying capacity of the lines are not urgently required. On the other hand, the cost of maintenance of lines and the number of wires on poles are serious considerations that weigh in favour of line saving.

In the giant new countries with magnificent distances, including the United States of America, Russia, Canada, South Africa, the Argentine, Brazil, and Australia, the saving of wire is of the greatest importance, and some waste of labour may be tolerated if there is compensating line saving. Here again we have a maximum problem. The relative advantages of line and labour saving have to be balanced to get the maximum benefit.

The foregoing considerations make it easy to understand that the amount of labour that must be performed by the human being, the head-work that cannot be done by a machine, in connection with commercial telegrams is always large, and in the nature of the case there can never be results in labour saving like those in industries where the great bulk of the work is of a simple routine character easily performed by machinery.

THE LABOUR-SAVING PROBLEM.

The difficulties in the way of labour saving in telegraphy may be roughly classed under two heads: those in connection with commercial messages, and those in connection with press messages. Dealing first with commercial messages, these are short and average about 20 words. Continual stoppages of the mechanism every 20 words are therefore necessary. There is no continuous run, and automatic factory production is not possible. At first sight saving of labour on commercial messages might appear to be easy, but investigation will show that it must of necessity be small. It is impossible to have a machine that will enable one man to do the work of 15 or 20 men, a thing by no means uncommon in the industrial world. A printing telegraph that would merely reduce the amount of labour by half would be a very fine system indeed, and it would effect very nearly the maximum possible labour saving. Take a printing telegraph that can run at 150 words a minute. If it could keep running continuously it would be able to turn out 400 messages an hour. But it has to stop every 20 words or less, and then there are corrections and repetitions and inquiries, also stoppages of the apparatus, breakdowns, line interruptions, pauses for adjustment, and irregular flow of telegraph traffic. All these causes lead to a sad reduction in the output and disappointment to the printing telegraph inventor. If screws never came loose, and metal never broke, and steel never wore out, and human beings never made mistakes, and if telegrams always came flowing in at the uniform rate of four a minute, printing telegraph systems would perform miracles of labour-saving, but they do not. With tape printing the tape has to be cut up and pasted on message forms and the messages signed and timed, the number of words counted and checked, and a note made of the preamble and address. With a page-printing telegraph the loss of time in cutting up tape and pasting it on message forms is saved, but provision has to be made and time allowed for line-feed, column-feed, and page-feed. These delays take place every 20 words or oftener, thereby considerably reducing the saving possible in theory.

The position is entirely different in the case of the stock-ticker and ticker news service. As in the case of the telephone and the telautograph, transmission in the case of the ticker is direct and there are no middlemen. There is no counting of the number of words in messages, no checking the messages, no questions asked from the receiving stations, no envelopes to be addressed, no registered addresses to be looked up, and no delivery of messages. In the case of the ticker practically the whole of the troubles are questions of mechanical maintenance.

PRESS MESSAGES.

Turning now to press despatches, the conditions at the first glance are much more favourable for printing telegraphy, but actual experience shows that the obstacles are much worse than in the case of commercial messages. It is true that press messages are long and therefore very favourable for machine telegraphy and for labour saving. The Murray automatic printer, for instance, can print news despatches easily at the rate of 200 words a minute. That is to say, it enables one man to do the work of six operators writing out messages from Wheatstone tape by pencil or typewriter. The service conditions, however, are so intricate that it is difficult to see how a printing telegraph could do anything more than a fraction of the work, at present at any rate.

The British system of news distribution is divided into the Post Office "News Division" worked by the Wheatstone system, and the leased and private wires rented from the Post Office by the leading British newspapers. London is the great originating and distributing centre for news, and it flows out from London all over the United Kingdom. The amount of news that comes up to London from the provinces is comparatively small. Taking first the Government service, in the British "News Division," news distribution is carried on by an elaborate arrangement of Wheatstone circuits, each message being perforated simultaneously on from one to eight tapes by pneumatic perforators, the tapes being then used to transmit press messages over as many as 30 different Wheatstone news wires, many of which have four or more towns strung on them in series. In this way news is distributed all over the United Kingdom at a very rapid rate, and with remarkable economy of labour, as one man can prepare a message for transmission to a hundred or more towns. There are very great difficulties in the way of any printing telegraph coming in and doing this work. In the first place, the news is distributed at a very high speed of from 200 to 300 words per minute. No printing telegraph can work steadily at such a speed on one wire. Also the Murray automatic system, and indeed any other printing telegraph using a special alphabet (not Morse), would require a piece of news to be punched in the Murray alphabet as well as in the Morse, unless the whole news service of Great Britain was handled entirely by the Murray automatic system. Apart from the speed difficulty and the cost of the apparatus, it would take years for a printing telegraph to be installed all over the country. Using it for a few circuits for news would mean double labour in perforating the message in two kinds of tape, one for the Murray and one for the Wheatstone. Other advantages might be great enough to compensate for this extra labour, but the speed of the line would have to be dropped to about 150 words a minute. It was for these reasons that the Murray automatic system was not tried on news work by the British Post Office when it was first brought over to London from New York in 1901. At that time also its speed was only 100 to 120 words a minute. The line speed has now been raised to a maximum of 184 words (1,104 letters) a minute and 200 words a minute for printing, but this is still insufficient for news requirements in Great Britain. Instead of news work it was put on to commercial work between London and Edinburgh. On that work quite different difficulties were met with. These will be dealt with presently.

A printing telegraph using the Morse alphabet would be more easily employed in the British "News Division," because it would fit in as part of the present news service. With this idea an inventor named Creed applied a differential feed to the Murray automatic printer so as to enable it to print messages from the ordinary Wheatstone Morse perforated tape. He also designed a very ingenious and useful receiving perforator to reproduce Wheatstone tape at the receiving station at a speed of about 150 words a minute. This worked quite well, for a time, but owing to its extreme complexity and its high cost, the Post Office only used the Murray-Creed printer to a limited extent. The British Post Office has plenty of wires at night available for transmission of news messages, so that a comparatively low speed, such as 150 words a minute, is not an absolute bar to the use of a printing telegraph; but it is not economical to have too many wires in use, because each wire requires a receiving clerk in constant attendance at each office. For instance, on the Scottish news, if an extra wire is opened a clerk is required in London, Newcastle, Edinburgh, Glasgow, Dundee, and Aberdeen—that is to say, six additional operators for one additional wire. This extra labour would be a considerable offset against any labour saving by a printing telegraph. It is possible that in time the Murray automatic system may come into use for news work. That is the purpose for which it was originally designed; but the prospects are not bright.

In other countries where there is no highly complicated arrangement for news distribution, there is no obstacle to the use of such printing telegraphs as the Murray automatic; but in countries where there is no complicated news-distributing organisation there is very little news traffic, and it can be handled easily by the Hughes and other low-speed and therefore cheap instruments. The field for news distribution by rapid printing telegraphs is not large outside of English-speaking countries, and inventors have therefore confined themselves chiefly to the more important field of ordinary commercial telegrams.

Another difficulty about news work is that in London and other large centres of population at least 12 copies are required of press messages for various newspapers. It puts a serious strain on any typewriter to make 12 copies continuously for long periods of time at a high speed. Rotary mimeographs and hectographs get over the difficulty in New York, and there is no reason why they should not do equally well in London.

As an illustration of the perfection of British news distribution, it may be mentioned that the British Post Office has successfully transmitted news at the rate of from 250 to 300 words a minute on a Wheatstone circuit from London, feeding Newcastle, Edinburgh, Glasgow, Dundee, and Aberdeen. In cases where a series of towns are strung on one wire in this way all the messages are sent through and each town picks out what it wants without asking any questions or interrupting the flow of news on the wire. In cases like this, and there are dozens of such circuits in the British News Division, a printing telegraph is at a grave disadvantage. A system worked in this way must not break down, and the high-speed printing telegraph that will not break down occasionally has not yet been invented. If one of the stations breaks down, the messages lost to that station must be repeated to all the five or more stations of the circuit. This involves delay and waste of labour, as each station will have four or five men, or even more, in attendance. Large stations will have 20 or more to write up the messages from the Wheatstone tape.

NEWSPAPER PRIVATE WIRES.

In the case of the private wires rented from the Post Office by British newspapers, the conditions that exist are even worse from a printing telegraph point of view. High-speed printing telegraphs are of necessity complicated and require good mechanical skill to keep them in order. All telegraph offices of any importance have several skilled mechanics to keep the telegraph apparatus in order, but newspapers have none. They have skilled engineers accustomed to large machinery, but small and complicated instruments are quite out of their line. That fact in itself is a most serious difficulty. It means that a skilled mechanic with an assistant and a small workshop would have to be installed. The question of speed also is just as serious with newspapers as with the Post Office. Take, for instance, a great provincial daily paper like the *Glasgow Herald*. Every night it sends from 30,000 to 40,000 words (about 30 columns) from its London office in Fleet Street to its Glasgow Office 400 miles away. The great bulk of this extraordinary mass of news is sent over the *Glasgow Herald* private wire between 5 p.m. and midnight, and the conditions are such that it is absolutely imperative to have a speed of transmission over the line of not less than 250 words a minute (1,500 letters a minute) and preferably 300, especially as the night advances and the time approaches for going to press. Even with such high speeds it is occasionally necessary for the *Glasgow Herald* to send some of its news over the Post Office wires. At present the work is done by the Wheatstone system, and there is a staff of 6 to 8 operators in London, who punch the news in the form of perforated tape, and it runs through the Wheatstone transmitter at 200 to 300 words a minute, coming out in the Glasgow office of the *Herald* as dots and dashes on a tape, which is then copied out by a staff of 8 to 10 men. It is not apparent how any printing telegraph can meet such requirements as those of the *Glasgow Herald*. The writer tried it with the Murray automatic system, but the utmost that he could achieve was 184 words a minute, and even this was with very fine adjustment, much too fine for practical work; 150 words a minute was practical, but it was too slow. Also the *Glasgow Herald* lays itself out especially for giving commercial news, and sends through from London every night several columns of stock and market reports. These are full of intricate figures, and a special system is adopted. There are printed sheets in the London and Glasgow offices of the *Herald* containing all the stocks and shares ordinarily quoted on the Stock Exchange. A letter of the alphabet is used for each stock or share, and they are arranged into groups distinguished by the names of colours, thus: Red *a*, *b*, *c*, etc.; blue *a*, *b*, *c*, etc.; and they are telegraphed thus: Red *a* 2 5/16 7/16, *c* 1 15/16, *d* 3½, etc.; green *a* 110–12, *b* 13 1/4, *c* 8 19/32, etc. Several columns of this have to be sent through without correction or revision of any kind, and there must be no mistakes. Under the present system mistakes are few. These prices are dropped into their proper places on the printed sheets in Glasgow by the operators who transcribe the Wheatstone tape. A printing telegraph that can do such work at 250 words a minute will take a lot of inventing. Less serious troubles are to be found in the fact that mistakes show up badly in the typewritten pages produced by printing telegraphs and make the sub-editors uneasy about the accuracy of the messages. In the case of the Wheatstone the transcribers correct the errors as they proceed, and they write out clean "copy." The sub-editors, seeing no mistakes, remain in happy ignorance of the frailty of telegraph lines and of human operators, and the editorial mind is at ease. News messages are also telegraphed with many contracted words. This saves time, but the contractions look bad in a typewritten message. When written or typewritten by hand, the contracted words are written out in full. Here is an actual example of a *Herald* message as it came through and was printed on the Murray automatic:—

> "SIR W ROBSON SD T GOVT CD NT ACCEPT T AMDT WH WD STRIKE AT T ROOT O T DUTY."
>
> "MR LLOYD GEORGE SD TT TO AVOID ANY AMBIGUITY HE WD MOVE AN AMDT WH WD MEET T POINT RAISED BY MR HILL."

The difficulties met with in connection with the *Glasgow Herald* private wire apply also in the case of other great British newspapers, such, for instance, as the *Daily Mail*, Manchester and Paris editions. These newspapers are all anxious to get some printing telegraph that will meet their requirements, but they are still waiting.

In spite of the great difficulties in the way of using printing telegraphs for news work it would be taking too pessimistic a view to say that printing telegraphs cannot be used for press despatches. They can be and they are so used. In Germany and France, for instance, where the newspaper telegraph traffic is small, all the press messages are sent over the Hughes and Baudot printing telegraphs, and even in Great Britain printing telegraphs will in time make their way for news work; but it will be a very slow progress and very costly. The apparatus will have to be faultlessly made and well-trained men employed to run it. There will probably be a saving of time, but the saving of labour will not be great.

THE "TOP COPY" DIFFICULTY.

It is the usual practice of telegraph administrations to keep a record of each message sent out for delivery. In some cases a note is made of the preamble and address. In other cases a copy of the whole message is retained. The custom of the British Post Office is to make a carbon copy of each message that is to be sent out for delivery, the original, or "top copy," being kept by the Post Office for reference and the carbon copy being issued to the public. When messages are written out by hand from the Morse sounder or from Wheatstone tape the making of a carbon copy of each message is a simple matter. The great bulk of British telegrams are dealt with in this way, but the gradual introduction of typewriters and printing telegraphs is rendering a change necessary, because it is not practicable to make carbon copies of messages when a typewriter or printing telegraph is employed. The reasons are as follows: In all countries there are two classes of commercial messages. In Great Britain these are known as S and X messages. The S messages are those for delivery to the addressees. X messages are those passing through town B from town A to town C. They are messages written down for retransmission over another circuit. These are not issued to the public and do not need to be copied. As much as half the traffic in large towns may consist of X messages.

In America wet press copies are taken of messages that go out to the public, and this method was proposed in London when the Murray automatic system was first started, in 1902, between London and Edinburgh, but various objections were raised to it. The Murray automatic printer could prepare from 12 to 16 good carbon copies of messages, but the carbon copy method could not be used because it was not possible to tell whether an S or an X message was coming over the wire at a high speed, and there was not time to slip in carbon paper for one message and not for another. Either all the messages would have to be carbon copied from a continuous roll or none at all. Arranging for carbon copies from a continuous roll was found to be very troublesome, expensive and impracticable. A variety of proposals were made. One was to have the platen of the typewriter itself covered with a jacket of typewriter ribbon material and a roll of tissue paper feeding in. The message would then print on the ordinary forms and give a tissue copy inked from the back by the ribbon cover of the platen. Investigation showed that this idea was not a good one. Another proposal was to blacken with the carbon composition the backs of the message forms, and they would then themselves supply a fine carbon copy on paper behind them. What the public would have thought of telegraph messages smudged all over the back with dirty carbon pigment is easily imagined. That idea was abandoned. The whole of the possibilities were gone through most carefully, and finally it was decided that the best way was to arrange for a "check-table" girl to make a written note of the preamble and address of all

S messages that came over the Murray circuit. As this work only occupied half the time of this operator, it was reckoned as the time of half an operator. Laboriously copying by hand at 15 words a minute with risk of error messages printed by a machine automatically at 100 or more words a minute does not seem very sensible, but it was the best thing that could be done under the circumstances, and it has been adhered to until quite recently. On the Hughes circuits also a check girl notes for record the preamble and address of Hughes messages. One reason for this arrangement is a good illustration of the complexity of telegraph work. The girl at the check-table was advantageously employed for this work because she was a "circulation expert," and, therefore, only copied S messages, her experience enabling her to tell at once which were S and which were X messages. For instance, "Silvergray, London," has to be delivered at Silvertown. It is therefore an X message and need not be copied in London. For part of Oxford Street, London, messages are delivered by tube, and part needs a telegraphic retransmission. Operators do not know the tube deliveries, but the circulation experts do. Of course, the whole of this trouble would disappear if the messages were press copied in the delivery office, where there are no X messages. Another proposal was that as the Murray automatic printer printed the messages from a perforated tape, any S messages should be printed twice by pulling back the tape and reprinting from it. This was tried and found to waste too much time. The only practicable method, therefore, is wet-press copying as done in America. There, a roller copier is used driven by a small motor. This was tried in London, but various difficulties were met with. Damping the sheets of tissue and handling the damp tissues proved anything but successful in the rush of telegraphic work. At that time the elaborate roller press copiers now in commercial use had not been developed. A photographic roller enameller was tried and with a few alterations gave good results. Bunches of tissue paper were soaked in water, and then run through the rolls to press out superfluous water, but the sheets were found to be so difficult to separate that much time was lost and the arrangement was impracticable. Also the damp tissue had a tendency to stick and wrap itself round the rollers of the copier. An American telegraph operator, who happened to be in London at the time, showed how it was done in America. Blowing sharply with the mouth on the edge of the mass of damp tissues separated them at the corners instantly, and enabled them to be pulled apart quickly. He also showed that 8 or 10 telegrams could be copied simultaneously by piling them up interleaved with the damp tissue sheets, folding the bundle in half, and running it through the rollers. The folding prevents the tissues sticking to the rollers and halves the time required to run through. In America, where the use of typewriters for telegraphic work is universal, the wet-press copying of S messages is done in the delivery office. This is simple and convenient; but when a new printing telegraph is being introduced in a country where messages are received by Morse sounder and written out with pencil and carbon paper, it is obvious that a press copying outfit cannot be installed in the delivery office for the sake of a few hundred telegrams a day, out of many thousands. That would waste much time and labour. Copying must be done near the receiving mechanism of the circuit until typewriting or printing telegraphy comes into fairly general use in the large towns. Also the copy must go with the message to the delivery office. It could not, therefore, be taken on a press copier using a continuous roll of tissue paper. The damp-press copies would also have had to go with the messages rolled up in bundles, through the pneumatic tubes, and that would have been liable to cause trouble. To avoid this difficulty it was proposed to use alcohol instead of water to damp the tissue paper, paper so damped giving an excellent copy from methyl-violet typewriting ink, and the alcohol dries quickly. The danger of fire, however, prohibited this idea. Under all the circumstances, copying the preamble and address by hand was the only thing possible. Recently the development of the modern press copier for commercial office use has brought the question up again. Rolls of tissue paper already damped with glycerine and water are obtainable, and these retain their slight dampness for a considerable time as the glycerine is hygroscopic. But these big press copying machines are useless in cases where the copying has to be done at the circuit. The cost of the copier for a single circuit, the space occupied, the labour, and the delay in cutting up tissue into separate messages to accompany the originals make it useless. In the delivery department one of these modern press copiers is very suitable, as all messages there are S messages and have to be copied, and one copier can handle the messages from many circuits. In America, before the introduction of the typewriter for telegraph work, the pencil and carbon paper method still used in Great Britain was employed. With the Morse key and sounder and hand-written messages this plan is ideal, because the operator has ample time to slip in a sheet of carbon paper when necessary. With the introduction of the typewriter there was no longer time to slip in carbon paper for some messages and not for others, and there was too much waste in copying all messages in this way when only about half needed copying. The Americans being more enterprising and less embarrassed by imaginary obstacles, wet-press copying in the delivery office was established as a matter of course.

In England another serious obstacle to the introduction of a rational method of copying telegrams was as follows: Some progressive officials in London, greatly daring, urged that the "top copy" should be done away with. They said, "Abolish it. We have the message as handed in by the sender, and if the recipient has any complaint to make let him produce the received message. We can then compare the two copies and see what is wrong, and refund the 6d. for the telegram if the Department is to blame." The abolitionists, however, have not been able to overcome the scruples of the Auditor-General of the Post Office, who for financial reasons has an elaborate system of checking the telegrams and the number of words paid for. The subject is really excessively complicated, and it has been dealt with fully here because it is a good illustration of the difficulties that the printing telegraph inventor has to face, subtle, invisible difficulties that even highly trained technical telegraph men do not themselves realise till they come up against them. Wet-press copying in the delivery office is rapid and free from error, and it is the only practical method of copying messages when printing telegraphs are used and when only some (roughly about half) have to be copied; and in time it will be adopted in all cases where a telegraph administration finds it necessary to preserve a copy of messages sent out.

S AND X MESSAGE FORMS.

The distinction between S and X messages has already been explained. X messages are well named because they cross through city B from city A to city C. An X message in city B becomes an S message in city C, where it is to be delivered. Not only do these two different kinds of messages give trouble in connection with making copies, but they also give rise to a further obstacle so far as page-printing telegraphs are concerned. Practically all administrations have two kinds of telegraph forms or blanks for the two kinds of messages. In the case of printing telegraphs like the Hughes and Baudot, which print their messages on a tape, the S and X message forms present no difficulty as the tape can be pasted on to either as may be required, and in any position. For instance, in France the piece of tape containing the address is pasted on the back of the message form, and in Germany in the middle at the top. Also in the case of the Morse key and sounder, it is an easy matter for the operator to select an S or X form as may be required. In the case of a page-printing telegraph, however, it is impossible to know whether an S or an X message is coming over the line until the printing of the message starts, and then it is too late to change the form, and it would cause too much waste of labour if the sending station had to announce beforehand whether an S or an X message was being sent. The only way out of the difficulty in the case of a page-printing telegraph is to have one kind of form for both S and X messages. Administrations are reluctant to make changes like this in their established forms. In Great Britain also there are two different forms for inland and foreign telegrams, C forms in the case of foreign and B forms in the case of inland messages. The same difficulty arises here also, and one form has to be used for both. Those who are sufficiently interested in the matter will find at the left-hand top corner of page-printed telegrams that they may receive in Great Britain the letters C or B, meaning that the form is to be used for either inland or foreign telegrams. When the Murray automatic page-printing telegraph was brought from New York to London in 1901, the British Post Office had to prepare a special telegraph form for it combining the S and X and the C and B forms, and to make it distinctive the heading was printed in green ink. A special form had to be adopted for it in Germany and other countries also for the same reason. Fortunately the advantages of page-printing are more than sufficient to counterbalance this initial inconvenience.

NUMBERING MESSAGES.

There are other difficulties that are confined to one Administration. For instance, in America and on the Continent of Europe it is customary to number each message consecutively. The receiving operator can then tick off the messages on the number sheet as he receives them. A missing message is noticed at once. The British Post Office used to employ numbers for messages, but eventually abolished numbering as it was found not to be absolutely necessary with the Morse key and sounder. Numbering was also abolished in the case of the Wheatstone. Instead, the "name to" of messages was written on slips kept for the purpose. This seemed unnecessary, and the messages were then run in batches of no definite number, and the "received" signal to the distant office was "RD batch" (received batch) at the conclusion. This rather loose practice has now been modified, and a record is again kept of each name and acknowledgments are sent in bulk. This means waste of time, but the numbering wastes line time, which is worse, especially when the line is in bad condition and there is no speed margin. Numbering messages involves a waste of about 2½ per cent. in line-time and labour, and as every signal costs money in telegraphy the tendency is to omit all unnecessary signals. Whether consecutive numbers on telegrams are necessary appears to be an open question. Certainly numbering is a safeguard against messages being lost—an accident that happens occasionally in all telegraph offices. Hence when the Murray automatic system was introduced into the British telegraph service it was considered desirable by the officials to resume the numbering of messages on the Murray circuit. This is a small matter, but it involved a certain amount of change of routine, and in a big department a change of routine is a matter of difficulty. It certainly is to the credit of the British and other telegraph Administrations that they have shown such willingness to make these and other considerable changes to accommodate the Murray and other printing telegraphs. The experience of the writer is that the real conservatives are not the official heads but the operators, who often show extraordinary reluctance to accept change of routine. In fact, that is one of the minor obstacles to the introduction of printing telegraphs. Of necessity, in the case of a new machine of this kind, improvements suggest themselves after months of practical experience; but by that time the operators have become accustomed to working the machine, and over and over again the writer has been told that improvements he had made were changes for the worse and that "the old machine was much better." It takes weeks before an improvement gives satisfaction to all.

COUNTING WORDS IN TELEGRAMS.

Following upon the numbering of telegrams comes the numbering of words in telegrams. This is a serious matter causing much waste of time and labour. It is a burden from which the telephone is free because the telephone charges by time and not by the number of words. Charging by the number of words is a very defective system, but it is difficult to say what better arrangement could be adopted. As long as word-counting remains in force it will be one of the hindrances to any considerable saving of labour by printing telegraphy. The number of words in the message is sent in the preamble, and it is the duty of the receiving operator to count the number of words in the received message to see that it agrees with the number in the preamble. If it does not it is a case of "wrong number." Suppose the preamble gives 14 words and the receiving operator can only count 13. He telegraphs back the recognised British inquiry signal "RQ" and adds "13 *w*." The operator at the sending station then repeats the first letter of each word in the message until the missing or superfluous word is found. This is a specially easy and quick process with the Morse key and sounder, but it is not so quick with any printing telegraph because talking back and forward is not so quick as with the Morse key. Counting the number of words in a message is a valuable check on the accuracy of transmission. Also the administration is bound to transmit the number of words that have been paid for; but the waste of time and labour on counting words is quite considerable. In telegraphy "wrong number" is one of the most frequent "RQs," and, in fact, when the apparatus and line are working well there is hardly any other. Often 60 or more messages will go through without a single correction or inquiry except on account of "wrong number." Probably in more than half of these cases the message has been correctly transmitted, but the number of words has been wrongly counted at the sending or at the receiving station, and an agreement has to be reached on this point before the message can be passed on. It seems an easy matter to count the number of words in a telegram, but in reality it is quite difficult and requires experience, and it makes the task of the receiving operator distinctly responsible. Not only may the sending and receiving operator count the number of words wrongly, but they may differ in their methods of counting. There are a very large number of words that may be described as more or less Siamese twins. You can call them one or two as you please. There are many official regulations on the subject. "Fishmerchant" is sometimes counted as one word and sometimes as two. The receiving operator has to ask sometimes how it has been counted. There are two Ashursts in England, and to distinguish the second one it is known as "Ashurst Hants," and this counts as one word equally with "Ashurst." There are hundreds of similar cases all over the world. Also there are many new Siamese twin words born almost every day, and lists of words to be counted as one or as two are issued from time to time. "Motor spirit" is counted as one word. The German word "Sagomehl" (sagomeal) is reckoned as one word in Germany but as two words in England. "OHMS," the contraction for "On His Majesty's Service," is counted as four words if in capital letters; but when printed in small letters, thus "ohms," it is the unit of electrical resistance and is one word. Printing telegraphs, however, usually employ capital letters and figures only. The words would then go in capital letters OHMS. On the other hand, in Germany small letters and figures only are used in telegrams, and the contraction for "On His Majesty's Service" would then appear as "ohms." This is not the only puzzle in counting words. According to the regulations of the British Post Office—

"Already" is one word,
"Alright" is two words.

"Errands" is one word,
"Erands" (contraction for East Rands) is two words.

"Blackbird" is one word,
"Whitebird" is two words.

"Three half pence" is one word,
"Three hundred" is two words.

"Motorbus" is one word,
"Motordriver" is two words.

"Motorboat" is one word,
"Motorlaunch" is two words.

"STCATHERINESONTARIO" is one word,
"PRESSASSN" is two words.

It is only fair to say that similar anomalies are to be found in the case of all telegraph administrations. They certainly do not smooth the path of the printing telegraph inventor.

Errors in Telegrams.

Apart from these difficulties, the most serious trouble a printing telegraph system has to face is errors in telegrams. The sender of a telegram may make a mistake, or his handwriting may be bad. The operator who transmits a telegram may make a mistake. The sending apparatus may cause an error. Disturbances on the telegraph line, stray currents, inductive interference, men repairing the line, wind and weather, may all introduce errors into a telegram. The receiving apparatus may cause a mistake. The receiving operator may not notice the mistake and the message may go on for retransmission to another town. The retransmitting operator may make a mistake, and the chain of points where errors may occur are repeated with each retransmission. Considering the possibilities, it is remarkable how few errors actually occur in telegrams.

In an ordinary message nine errors out of ten in words are sufficiently obvious to induce the receiving operator to ask the transmitting station for confirmation or correction. With figures, on the other hand, the context is no guide, and a mistake in figures is not detectable by inspection. In cipher messages containing groups of figures, the code maker's practice of adding up each group of figures and telegraphing the total as a check can be followed. This plan has the advantage that the check signal is brief, but it does not guard against horizontal transposition of the figures unless the adding is done vertically. Assume, for instance, that the message contains the figures 23 371 27 17 6. Adding up these figures horizontally gives 39, which again gives 12, which finally gives 3. Obviously any transposition of these figures will make no difference in the total, and the error of transposition is very common. Addition guards against a wrong figure, but it does not guard against two wrong figures cancelling each other's error so as to give a correct total—7 and 3, for instance, instead of 6 and 4. The chances against this are large, but it is possible. Also it does not guard against a wrong figure and a wrong addition neutralising the wrong figure. The chance of this, however, is very small. Adding the figures vertically we get—

$$23 + 371 + 27 + 17 + 6 = 444.$$

Any horizontal transposition will show at once in this total. Further additions, however, will give the same total 3 as before. That is to say, three 4's are 12, and 1 and 2 are 3. The figures can be transposed in any possible way vertically or horizontally, and the total will always be three. As a check for a few figures addition is of little value, but for long cipher messages it is a useful though not infallible check.

Repeating the figures is a check always used in the British telegraph service with the Morse key and sounder, but this also is not a perfect check, because the human mind is so liable to fall into habits; and if an operator sends a wrong figure he is very liable to repeat his mistake when repeating the figures at the end of the message. Also if an operator receives wrongly the error is liable to go unnoticed in spite of repetition, especially 3 for 4 or 4 for 3 in Morse, these Morse figure signals, when repeated, differing only by a single dot, thus :—

3 - - - ——
4 - - - - ——

With keyboard sending there is the additional risk that some defect may develop in the instrument, causing a particular figure to miss occasionally, and repetition of the figure will be liable to repeat the error. The human failing is thus paralleled by the machine. This rarely happens with any of the good modern keyboard instruments for sending, but the possibility is there. A figure check that is practically perfect was suggested by Mr. W. A. Hatfield, a member of the British Post Office engineering staff. It consists in the repetition of figures that occur in the address and text of the message as letters at the end of the message—thus: $a = 1$, $b = 2$, $c = 3$, etc. This is taken from the British telegraph clock code time, in which $a = 1$ o'clock, $b = 2$ o'clock, and so on. This code is well known to the British telegraph operators. Hence its use as a figure check in the British telegraph service is very easy. In any case it is not difficult to learn. It will be noticed that different keys are employed to repeat. This guards against an error due to a defect in one figure key being repeated, and it also prevents the operator repeating an error through habit. The arrangement was adopted with the Murray automatic system, the figures being repeated as letters in a separate line at the bottom of the message. This reduces the output of messages, probably by about 10 per cent., but it is an admirable safeguard, particularly in the early stages of a printing telegraph system before all the mechanical troubles have been overcome. When cipher messages consisting of groups of figures are being transmitted, the repetition of figures as letters is cumbersome, and transmission at the end of the message of the sum of each group of figures would probably be the best check. Up to the present the code makers are the only people who have availed themselves of this plan.

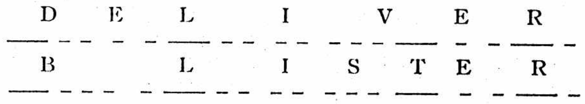
The great majority of the small errors made on keyboards are transpositions of letters, such as "aer" for "are." Some of these transpositions are rather puzzling. For instance, "Sne dat once" needs a moment's thought to see that it should read "Send at once." This was an actual mistake, and it is interesting because it is a case of double transposition. *E* and *n* are transposed and then the space and *d*. Double transpositions are not uncommon. When the mind stumbles it often stumbles again in trying to recover itself. Other errors of this kind that have actually occurred are "Engaldn" for "England" and "Metnsh" for "Months." Transposing is a common error also in writing. It is not confined to typewriting.

It is necessary for the operator to have considerable experience of telegraph messages to perceive mistakes. For instance, "fmcht" is clearly a mistake to any one not acquainted with the subject, but it happens to be the customary contraction for "fishmerchant." A good example of the care and discretion necessary in checking received telegrams is as follows. One day a telegram came through something like this, "Buy 100 tintos for ries." Apparently the sending operator had fallen into the usual error of transposing. He had mixed the *e* and the *s*, and the telegram should have read, "Buy 100 tintos for rise." Fortunately the receiving operator asked the sending operator whether "ries" was right, and it was. That telegram came through without error, but it involved delay and an inquiry. There are many such telegrams, and they materially reduce the number of messages that an operator can handle per hour, and thereby increase the cost of telegraphy to the general public. On the telephone there would have been no doubt about that message and no delay. If telegraphy was straight-ahead routine work in a steady, continuous stream all day, without any need for head-work on the part of the operator, telegrams would only cost a quarter of what they do now, and the printing telegraph inventor would have an easy task.

Another fertile source of errors in telegrams is careless and indistinct handwriting on the part of the public. For example, cruisers certainly are bruisers, and the British Admiralty would like to be Almighty, but a certain editor must have been rather surprised when he got a telegram announcing that "The Almighty has ordered three new bruisers." In this case the operator was also to blame for allowing such nonsense to pass, but in the following instance the operator was not at fault, as the mistake probably arose from the use of the old-fashioned *s*, written very like *f*. A man in London told his wife in New York to come over to London by a certain steamer, and then at the last moment decided to go to New York himself and accordingly telegraphed to his wife, "Don't sail." The telegram as it reached his wife read, "Don't fail." She took it as instructions to sail without fail, and she did so, only to find on arriving in London that her husband had also sailed without fail to New York. Another class of errors is that due to defects in the apparatus. Printing telegraphs, especially new ones, drop letters occasionally. In one instance in London the letter *z* was missed from the address "Zurich," so that the message read "Urich." By some unhappy chance there is a town named Urich in Montana, in the United States, and the telegram accordingly went to America instead of Switzerland. The mistake was not discovered till the message had come back from Urich in America, undelivered, two days afterwards.

On the other hand, it is the general experience that good printing telegraphs reduce the number of errors in telegrams compared with the Morse key and sounder. Printing telegraphs eliminate a whole class of errors due to misreading of Morse signals. Also signals sent by a machine are of necessity more precise and accurate than hand signals can possibly be. It is for this reason, amongst others, that automatic transmission is now practically universal on ocean cables. It is an undoubted fact of experience, both in Great Britain, the United States, and other countries, that printing telegraphs, when in satisfactory working condition, reduce the percentage of errors very materially compared with the Morse key and sounder.

As an example of a Morse error the following may serve. A message was handed in at an office in Ireland: "Deliver ten pigs." This was mutilated in transmission into "Blister ten pigs." The Morse signals are identical, but the spacing differs, thus:—



Complaint was made about the pork and mustard error, damages claimed, and sixpence, the cost of the telegram, was refunded by the Post Office.

Not only is long experience necessary for the quick detection of errors, but familiarity is also desirable with the traffic on particular circuits. Registered addresses are often peculiar, and slight mistakes on the part of the sending operator might cause a wrong delivery of a message. Experience on a circuit will detect such errors at once, as registered addresses occur frequently on particular circuits and become familiar to the receiving operator. Also the usual trade contractions must be known—for instance, "fmcht" for "fishmerchant." "Ystradyfodwg" is a real name, though it does not look right to the uninitiated. "Gwrwch," another Welsh town, is also correct, although its looks are against it. "Gablonzanderneisse" is obviously correct, and "Steatherinesontario" and "Stmaloilleetvilaine" are quite right and count as one word each. Printing telegraphs occasionally become what the French call "derailed" for a few seconds, and a meaningless jumble of letters is printed. Fortunately this kind of error is recognisable after a little experience, as the "derailment" gives characteristic results with each kind of printing telegraph. Hence the only evil consequence is a little delay. Code and cipher messages are also a sore trial for the telegraph operator, but such messages come through, on the whole, more accurately on a good printing telegraph than with the Morse key and sounder.

The method of getting corrections and making inquiries is ingenious and brief. R Q is the British signal for an inquiry, and the following contractions are used—

A A = All after.
W A = Word after.
L W = Last word.
M M = Office of origin.

"What is the word after urgent in message No. 125" would be sent "125 W A urgent." If the last word is in doubt, the inquiry would be "125 L W." The sending operator also anticipates inquiry in regard to curious words by repeating them at the end of the message. This saves time.

Variety and Irregularity of Telegraph Traffic.

A special difficulty for printing telegraphs is to be found in the variety and irregularity of telegraph traffic, which varies greatly in volume and in character according to the circuit and the seasons. In Great Britain, for instance, the telegrams from the Channel Islands are largely telegrams about early potatoes and other produce, and they are in many cases "multiple address" messages—sometimes two addresses, sometimes three, sometimes a dozen or twenty. Other circuits have heavy fish-traffic, such as Grimsby. Others, like London to Brighton, are largely social and domestic. There are great variations of traffic according to the seasons, and much more traffic in summer than in winter, at any rate in Great Britain. There are also great variations in the volume and kind of traffic according to the hours of the day. British telegraph traffic divides itself quite distinctly thus :—

7 to 9 a.m.—Fish and meat telegrams (provision market work).
9 to 11 a.m.—Births and deaths and a little Stock Market.
11 a.m. to 1 p.m.—Stock Market and commercial messages.
1 to 4 p.m.—Racing, betting, and ordinary telegrams.
4 to 5 p.m.—Ordinary messages.
From 6 p.m. onwards, Press messages.

The work is quite distinctly divided in this way, and the telegraph operator can watch the habits of the people, when they get up, when they start work, and so on. The number of betting telegrams in Great Britain is very large, especially from Ireland. There will be a considerable loss of revenue to the British telegraph service when the law finally puts a stop to this betting vice. There are similar irregularities in the traffic between Great Britain and the Continent. For instance, from 8 to 10 a.m. Berlin has a lot of traffic to send to London, and London has little to send to Berlin. From 10 a.m. to noon the flow is about equal in each direction. Berlin begins to slacken down after midday and remains slack till after 4 p.m. After noon London sends more than Berlin. On fish circuits in Great Britain, Grimsby and Aberdeen are very busy from 7 a.m. onwards, both with railing fish and prices. Queenstown and other big ports are busy all night with arrivals and departures of boats. Each boat arrival at Queenstown means, perhaps, 100 messages to large hotels and friends.

Multiple Address Messages.

It frequently happens that the same telegram has to be sent to a number of different people. These are known as multiple address messages. One source of such messages is pigeon-flying. This sport is very popular in England, and during the pigeon Derby, pigeons are sent from all over the country to one place and liberated. As many as 900 or 1,000 telegrams are sent off to the various owners of the birds, mentioning the time of liberation and the direction of the wind. The text of these messages is the same in all ; the addresses only vary. These addresses are usually given to the Post Office a day or two beforehand. They are received in the head telegraph office in London and copied out on thin telegraph forms and kept in readiness. At the time when the pigeons are liberated a single telegram comes through to the London telegraph authorities, who promptly start manifolding it in batches of six or more on the previously addressed message forms. The filled-in messages are then sent from London by telegraph all over the country to the given addresses. Obviously a printing telegraph cannot do this class of work. Multiple address messages of 1,000 addresses are not common ; but messages of from 6 to 12 addresses are frequent enough, especially from the Channel Islands. It is difficult to see how they could be dealt with by a printing telegraph. Sending the address and text of each separately would be too slow. The addresses could be sent easily enough, but this text would have to be typed or written in by hand with the aid of carbon paper, or hectographed. Racing and betting telegrams are also responsible for many multiple address messages. The number of telegrams sent out by tipsters and betting men in Great Britain is extraordinary. A tipster, say in London, who has been lucky enough to select two or three winning horses, advertises the fact, and so gets many hundreds of clients, to whom he sends out a multiple address message, recommending them to bet on several horses as certain winners. The addresses come through and then the text, and this text is manifolded on the addressed forms. If there was any regularity about this procedure some printing telegraph arrangement might, perhaps, be devised to deal with it by modern methods of duplicating, but the tipster's profession is precarious. During a lucky week his *clientèle* may swell into hundreds, and then after a few bad selections of horses the number of his clients will dwindle away to nothing. The tipster keeps quiet for a week or two, until his bad advice has been forgotten, or changes his address and makes another lucky hit in "spotting winners." Then up goes his reputation once more, and once more multiple address messages go to hundreds of clients. That is hopeless from a printing telegraph point of view. Hand work must come in in such cases. One of the most famous multiple address messages was that sent out by the London *Times* when selling the "Encyclopædia Britannica." That ran into 24,000 addresses.

Traffic Arrangements and Hours of Duty.

The telegraph service in all large Administrations is very highly organised, and printing telegraphs introduce considerable changes, which cannot be effected without a good deal of trouble. Telegraph work is very irregular, and it is at its maximum only for a few hours a day, at least in Western European countries. Consequently it requires very ingenious and complicated arrangements of the hours of duty of the operators, and close attention to the average number of messages per operator, per hour (or more briefly, "operator averages"), to prevent waste of labour under such conditions. If, on an average of, say, three days' work, there is found to be extra pressure of traffic between two towns, then an extra channel is opened, or *vice versâ* a channel may be closed. Men are shifted back or forward as the traffic requires. If two wires do not supply enough work for two operators, then one operator has to attend to the two wires, and so on. Then there may be a rush of work in the news division, and men have to be drafted in from other divisions to cope with it. Or sometimes, when there is heavy pressure of traffic between two towns, traffic may have to be diverted through other towns. Various divisions of the telegraph office in London help one another in this way. Printing telegraphs necessarily vary these arrangements considerably. In countries like Great Britain, with very heavy telegraph traffic over short distances between busy towns, the traffic arrangements are very complicated indeed. Important sittings of Parliament also involve heavy news work, and there are often late sittings. All this upsets arrangements. There is also constant pressure from above on the supervising staff to maintain good operator averages. The officials have, therefore, worries enough to keep the old-established routines going, without having them upset by new printing telegraph systems. Fortunately, the Murray automatic system fitted in rather well with the habits of the British telegraph officials, who had had long experience of the Wheatstone automatic. The best methods of organising traffic for an automatic system were familiar to them. Some of the Wheatstone customs were a hindrance, but on the whole the Wheatstone experience was very beneficial.

On the Continent of Europe there has been long experience with the Hughes printing telegraph, which handles the bulk of Continental traffic. There are plenty of skilled mechanics, and all telegraph offices of any size at all are provided with a repair workshop. On the other hand, the use of the Hughes printing telegraph at once limits the employment of new printing telegraphs unless they are of quite exceptional merit. Also in France the Baudot printing telegraph holds the field against any other system. Each country has its own arrangements and methods of dealing with telegraph traffic. The class of operator employed in each country also varies greatly. In America and Great Britain and Russia, and indeed in most other countries, female as well as male operators are largely employed. In Germany, on the other hand, male operators are chiefly employed, and they include many old soldiers, good reliable men, but as a rule not so rapid as men who have learnt telegraph work early in life. In Great Britain no record is kept of the messages as transmitted at the sending station (except the original messages as handed in), but most countries on the Continent of Europe insist on a "home record." The Murray keyboard perforator tape is a good home record, and is accepted for this purpose by the German and other Administrations using the Murray apparatus. Keeping a home record, however, involves extra labour to wind up the tape.

In Germany the Hughes methods were an assistance to the Murray automatic system, and also a hindrance, just as in England the Wheatstone system was a help and a hindrance. With the Hughes, which prints its messages on a tape, it is necessary to insert special signals to distinguish the preamble from the address and the address from the text, and the text from the signature, and also to indicate the end of each message. With a page-printing telegraph these printed special symbols are not necessary, as the printing machine does the work automatically; but it was only gradually that these Hughes signals were abolished in the case of the Murray system, and not until it was demonstrated that Hughes methods applied to the Murray automatic system caused a distinct loss of time and labour. Hughes operators, when put to work on the Murray keyboards, found it difficult to break away from their Hughes habits. In England the change of telegraph forms from two kinds (one for S and one for X messages) to one form for both kinds of messages was made without difficulty, except in regard to the large "TO" that used to be printed at the beginning of the address in British telegrams. This "TO" seemed to be sacred, in spite of the fact that page-printing telegraphs must necessarily often print the address right through the "TO." After several years the G.P.O. finally agreed to omit the precious word. Other far more radical changes were agreed to quickly and without demur. These trifles all adjust themselves in time.

The differing conditions even in neighbouring countries in Europe are surprising. In Germany the operators are, by law, responsible to the outside public for mistakes, and may be sued individually for damages. The Government is not responsible. To safeguard themselves the operators tried an insurance scheme; but as soon as the existence of the insurance fund became known to the outside public, actions for damages became numerous and the fund soon faded away, so the writer was informed in Berlin. Now the operators prefer to trust to a personal appeal, and, as they have to deal mostly with good fellows, the appeal is generally successful. The possibility, however, is unpleasant, and checking telegrams very carefully is universal in Germany, and operators are never blamed for going slow. You can rely on a German telegram being accurate. Mistakes occur, but they are few compared with those in English-speaking countries. In Austria the individual operator is not liable for damages for mistakes. Also the "tantieme," or bonus system, prevails. They get a percentage on the number of messages they transmit. The same system is in force in the United States. The result is the "Tantieme Jäger" or percentage hunter, and the Austrian Tantieme Jäger is the nightmare of the careful German operator who wants to go slow to avoid mistakes. In Russia there is a much more pleasant and easy-going state of affairs, and afternoon tea is an established institution, as in London. In Russia the telegraph traffic flows along majestically like one of Russia's own rivers, without haste but without rest. Russia is a continent with day in the east while it is night in the west. Hence long-distance traffic in Russia flows continuously right round the clock. On such long lines there is no extreme urgency about transmission of telegrams in a few minutes. If they are delayed for an hour or so in transmission over 2,000 or 3,000 miles there is no harm done. This also tends to equalise the flow of the traffic. These conditions are very favourable for printing telegraphs, and during the last few years Russia has gone in extensively for machine telegraphy, with quite satisfactory results. On the other hand, on the long Russian lines a printing telegraph has to work through much longer hours than in England. In England there is very little telegraph traffic at night

except press messages, and the bulk of the traffic clusters round the hours between 10 a.m. and 3 p.m. The result is that a printing telegraph in England can only be used to its full capacity for a few hours a day. In Russia the machines have to work fully fourteen hours a day on many lines. They have, therefore, in many cases, to do about three times as much work per day as in England.

INTERNATIONAL CIRCUIT TROUBLES.

In Western Europe there are two very serious handicaps on telegraphy, and therefore on printing telegraphy. These are: (1) The comparatively small areas over which undivided authority exists, and (2) the differences in language. The prime conditions for extensive use of telegraphy are a large and well-educated population speaking one language and spread over a continental area. These conditions exist to a high degree in the United States of America, and in the United States telegraphy is making remarkable progress, in spite of the competition of the telephone. In fact, the telephone assists. There is also one language and a continental area in Canada, Russia, Australia, Brazil, the Argentine, and South Africa. When these new giant world States have grown up, telegraphy will take on a very different aspect from what it has now. Telegraph traffic will be enormous; printing telegraph inventors will come into their own, and there will be printing telegraph millionaires in those days. Meanwhile the printing telegraph inventor has to wear the mended shoe, because the growth of the telegraph service is cramped by the smallness of European States like England, France, and Germany, and by the differences of language, and by the division of authority. Differences of language and political divisions have confined trade in Europe within comparatively small national boundaries, and long-distance telegraph traffic in Europe is very small compared, for instance, with the United States.

Apart from the language difficulty, the worst evil on these international European circuits is divided authority. The operators at each end of these circuits are quite independent of each other, and the officials at one end have no control over the other end of the line. Under such conditions a certain amount of friction and lack of harmony is inevitable. The London operators, for instance, say that they have always to give way and do what the Continental operators want. The Continental operators, on the other hand, say that the London operators are the most obstinate people in the world. In spite of this, or perhaps because of this, there is much politeness on these international circuits, and frequent "Yes, Mister," and "No, Mister." To such an extent is this carried that a London operator remarked indignantly to the writer: "Every R Q means a sermon with these foreigners and half-an-hour's delay." If the European international lines came under the control of an American manager he would issue an order something like this. "Don't clog the wires with polite expressions. Take them for granted or send them by post. *Every signal costs money.*" Unfortunately Anglo-Saxon brusqueness gives offence on the Continent. The one desire of the English and American telegraph operators is to move the traffic, and they drop all polite formalities. The Germans are tending in the same direction nowadays, but the Latin nations stand on their dignity, and are very "touchy." London operators have been schooled into a knowledge of this peculiarity and make the necessary allowances for it; but there is a story that Liverpool got a direct Hughes wire to a certain French town. Liverpool started speaking to the operator in the French town as Liverpool was in the habit of speaking to London. The result was silence. The French operator simply left the circuit for three days. Liverpool had to send its messages *viâ* London as of old, and had to ask London to mediate. London was told by the French town that when competent operators were sent from London to Liverpool to work the direct wire, the French town would resume direct telegraphic intercourse with Liverpool. That is a characteristic experience on a good many Continental wires, and it does not smooth the path of the printing telegraph inventor.

ALPHABETICAL TROUBLES.

Not only is there great difficulty in getting a printing telegraph to work perfectly and to save time, labour, and telegraph line; but also, if it is to go into extensive use, it must have sufficient elasticity to fit in with the requirements of various telegraph administrations. Reference has already been made to the varying conditions to be found in different parts of Europe. One of the most serious difficulties arises out of lack of uniformity in language. The general effects of the limits imposed by diversities of language have already been referred to, but there is one special aspect of this matter that needs further attention. Out of the varying languages spring varying alphabets, and a printing telegraph suitable for use in English-speaking countries is by no means suitable forthwith for countries using another language. Out of these varying alphabets spring up several mechanical troubles. One of the chief mechanical problems in a printing telegraph is the same as in a typewriter, namely, to bring any one of a given number of type to one printing point and to return it to its position of rest in the shortest possible time. The size of the type which it is convenient to read and which prints clearly under typewriter conditions has an important bearing on the question. There are fairly definite limitations in regard to the size of the type. There are also limitations to the number of type if operation is not to be very slow. A typewriter, for instance, with 10,000 different characters would have typebars 15 ft. long, or if it was a type-wheel machine the type-wheel would be over 10 ft. in diameter. Typewriters seldom have more than 90 characters. That is about the limit of what is practicable. Serious mechanical difficulties arise with the introduction of any greater number of characters. With printing telegraphs there are still further limitations arising out of the codes of signals. These impose a practical limit of about 50 to 60 characters. For instance, with the 5-unit alphabet used in the Baudot and the Murray systems, there are 32 possible signal groups (permutations of five things taken, 1, 2, 3, 4, and 5 at a time). By using a shift key this number can be doubled, but as the space signal and two or three operation signals have to be provided for there are practically about 54 characters that it is possible to transmit with the 5-unit alphabet. A second shift key may be used, giving about 120 different characters, but two shifts entail too much loss of time in operation, and it is very desirable to adhere to one shift only. As we are confined to about 54 characters, and as we have to provide 10 numerals and about 15 punctuation marks and other figures, it is not practicable to provide both capitals and small letters. It is usual in printing telegraphs to employ capital letters only, but the German Telegraph Administration prefers small letters only, scientific investigation having shown that small letters are more distinct and easily read than capital letters. There is no difficulty in providing for that difference in practice; but when we are limited to 54 characters, and when each country requires some special character—usually several accented letters—the difficulty in the case of a printing telegraph that aspires to be used internationally becomes serious.

Looking through the alphabets of the leading languages of Europe (excluding Russia, which has a special alphabet of its own) we find the following characters :—

COMMON TO ALL.

a b c d e f g h i i k l m n o p q r s t u v w x y z 1 2 3 4 5 6 7 8 9 0
. , ? — ( ) ' " / %

SPECIAL CHARACTERS.

Germany.—The three modified vowels *ä, ö, ü,* although in general use in all printed matter in Germany, are not employed in the German telegraph service, *ae, oe* and *ue* being used instead. Germany follows closely the International Telegraph Convention list of characters, and therefore requires—

: & ! ; =

Austria.—Special requirements in Austria are—

š ž ř ň č # !

Hungary.—In the Hungarian language there are a variety of accented letters, amongst others the following :—

ő ó ö ú é á

Italy.—The grave accent is used with all the vowels in Italy, but in the telegraph service only *à è ò ù* are employed, and these only in Morse. For the Hughes the accents are dropped, and for the

Baudot the Baudot characters are employed. é is practically the only accented letter actually employed. It is substituted for *w* in Italy and in the Italian telegraph service to France.

France.—The accented letters *é è à* are common in French words, but only *é* is used in telegrams. In the Baudot system, in addition to the letters and numerals and the International Convention punctuation marks, there are a number of special characters as follows :—

é F̲ H̲ o̲ N°· ✱ ʻ

Norway.—The telegraphic alphabet employed in Norway calls for—

: *æ ö é* " = !

Sweden.—The telegraphic alphabet used in Sweden provides for—

å ä ö : ; *é* !

Spain.—The International Telegraph Convention alphabet is closely followed in Spain. The Spanish accented vowels are the reverse of the Italian and carry the acute accent—

á é í ó ú ñ

but they are not used in telegrams, except *é*, and it is only on very rare occasions that it is necessary to explain at the bottom of a message that a vowel in a certain word is accented. *n* is usually employed for *ñ*.

England.—The confusion between fractions and shillings through the use of the fraction stroke / has recently led to the employment in the British telegraph service of the special character | as the shilling stroke, the sloping / being kept for fractions. A special character has also been introduced to separate whole numbers from fractions thus, 2⁀3/8. Otherwise there are no special characters required in English telegrams, and there are no accents in the English alphabet.

International Convention.—The alphabet provided by the International Telegraph Convention, in additional to the 26 letters of the alphabet and 10 numerals, employs the following punctuation and other marks :—

. , ; : ? ! ' " + − / = ( ) & ×

Several of these characters are quite useless for telegraphic purposes, as they are never required. No one ever wants to telegraph a semicolon, for instance. The Administrations, however, adhere to the Convention more or less and the characters have to be provided.

Cable Companies.—Most of the cable companies provide Morse signals for—

ä á or *å é ñ ö ü* ! ; :

but they are seldom required.

Esperanto.—The Esperanto alphabet only calls for notice as an amusing curiosity. It employs the circumflex accented letters—

ĉ ĝ ĥ ĵ ŝ and *ŭ*.

One of the chief advantages of an international language would be for international telegrams, but it is not quite clear how these accented letters are to be telegraphed.

Russia.—The Russian language is provided with a commodious alphabet of its own with 36 characters. It is impossible to send telegrams in this alphabet outside of Russia.

Japan.—The Japanese language is represented by an alphabet of 48 letters, 10 numerals, 7 punctuation and other marks, in all 65 characters. As in the case of the Russian alphabet, it is impossible to send telegrams in the Japanese alphabet outside of Japan.

Summing up, it will be seen that any printing telegraph system aspiring to suit merely the leading European languages, excluding Russia, would have to provide—

26 ordinary letters of the alphabet.
10 numerals.
18 punctuation marks.
16 accented letters and other special characters (probably more than 16).
—
70 characters in all.

In the Murray systems the difficulty was overcome by providing an international keyboard and reserving seven characters for national use, as in Fig. 1.

The secondary positions on key buttons S D F G H J K are reserved for national characters to be used in telegrams not passing out of one country. The idea is that a telegram using only the international characters shown in the diagram can be transmitted and retransmitted automatically on the Murray systems on Murray circuits on any international lines to any point required—for instance, from Dublin through London and Berlin on to St. Petersburg.

This keyboard arrangement worked satisfactorily until the Murray system was installed in Sweden. It was then found that *w x* and *y* are seldom used in Sweden, and *å ä* and *ö* are frequently used. Owing to the loss of time arising from putting them in the secondary positions for national characters, it was decided to put these accented letters in the place of *w x* and *y* in the primary positions, *w x* and *y* going into secondary positions. This has made a break—the only break, so far, in the internationality of the Murray systems. In Norway they adhere to the international arrangement of the Murray keyboard.

In Russia the alphabet difficulty appeared at first sight to be insurmountable, because a printing telegraph in Russia must print both Roman and Russian letters. As there are 26 Roman letters and 36 Russian and 10 numerals, and about 15 other necessary figures and punctuation marks, we have about 87 characters in all to be provided. The Hughes and Baudot systems, both of which are extensively used in Russia, overcame the difficulty by providing two distinct type-wheels, one with Roman type and the other with Russian type. When in a Russian message a word in Roman letters has to be transmitted, the sending operator has a special call to attract the attention of the receiving operator, who then shifts the type-wheels on their spindle so as to bring the Roman letter-wheel into printing position, and *vice versâ*. This rather clumsy device serves its purpose well, but it is not applicable in the case of a typebar typewriter like that used in the Murray automatic system. It is also not automatic. In the case of the Murray automatic system the difficulty was overcome as follows :—

Out of 36 letters in the Russian alphabet only about 33 are really necessary, and one of these bI, can be printed by using two other letters. This leaves 32 characters to be provided; 13 of these are the same as the Roman alphabet though representing different sounds. H, for instance, in Russian represents the Roman N; P is R and C is S. This reduced the number of characters required to print both Russian and Roman to 64. This was practicable, and it was provided by two shift keys. One key shifts from letters to figures and the other key shifts from Russian to Roman letters. The selecting mechanism is necessarily very intricate to meet such requirements, but once it is made it works well and easily, and it is automatic—that is to say, the printing of Russian or Roman letters and figures at the distant station is done entirely by the sending operator.

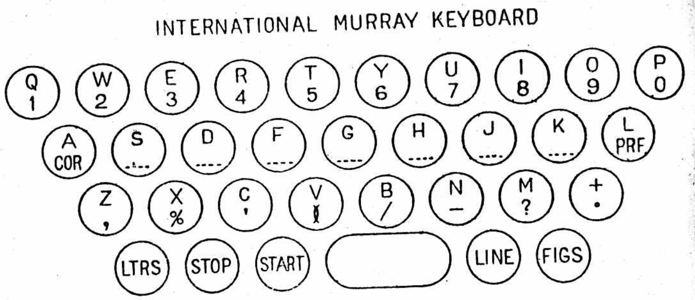


FIG. 1.

The Russian Murray keyboard is shown in Fig. 2.

One way out of these difficulties would be to use the 6-unit alphabet instead of the 5-unit alphabet. This would provide 64 signals, and 64 keys and no shift keys. It would meet the requirements of nearly all languages, but it has the serious drawbacks that it would increase the complexity of the apparatus in the ratio of 5 to 6, and double the size of the keyboard and the number of keys; and worst of all, it would increase the number of signals on the line from a trifle over five to six, an increase of nearly 20 per cent. This would be a distinct handicap in the case of long or

difficult lines, but it would still be shorter than the Morse alphabet in the ratio of 6 to 8, in the case of the Murray automatic system. In the case of the Murray and the Baudot multiplex systems correcting and retardation segments would bring up the length of the signals nearly to the level of the Morse. It would also necessitate the abandonment of the use of a letter-shift printing mechanism corresponding to the shift-key typewriters. This would practically double the complexity of the printing mechanism in the case of the multiplex. The full non-shift keyboard with a separate key for each character is undoubtedly a little quicker than the shift-key keyboard; but the gain is only about 5 per cent., and most printing telegraphs have adopted the shift-key arrangement in preference to the extra complexity of mechanism and reduced line efficiency of the "one key one character" arrangement with its longer code of signals. The same problem confronts the typewriter manufacturers. The full keyboard non-shift key typewriters are undoubtedly somewhat more rapid in operation than the shift-key machines, but the number of shift-key typewriters, especially those of the Remington pattern, greatly exceeds the number of the full keyboard typewriters.

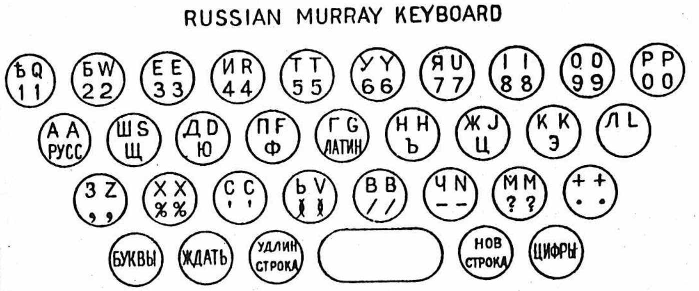


FIG. 2.

In the case of Japan, the alphabet difficulties are more serious even than in Russia, and the 6-unit, or some correspondently lengthened code of signals, will be a necessity. In Japan, Roman letters are not in use, and there is a special Japanese alphabet of 48 letters, 10 Arabic numerals, and 7 punctuation marks and accents, in all 65 characters as a minimum. Also, instead of reading horizontally from left to right, the Japanese read the lines vertically from top to bottom of the page and pass from line to line from right to left. It is exactly like reading a European book turned round to the right till the lines are vertical. A still more formidable difficulty is that the Japanese alphabet is used mixed up with Chinese ideographs. For this reason, up to the present, it has not been possible even to use typewriters in Japan. Some books are printed in Japan with the Japanese alphabet only, but it makes the books very voluminous. The Chinese ideographs are really a system of shorthand, one character representing one word. This greatly reduces the bulk of a book. With the exceptions of the ten ideographs, which we call Arabic numerals, it is impossible to telegraph ideographs, because we cannot spell ideographs, and spelling is the foundation of telegraphy. For telegraphic purposes in Japan it was therefore necessary to use the Japanese alphabet only, and the existence of a Japanese alphabet was found to be a very great assistance in the rapid spread of telegraphy in Japan. In addition to the 48 Japanese letters there are also 25 umlaut, or accented characters. Fortunately, as the accents are above the letters and as the letters are written in vertical columns, the accent can be printed as a separate character before and therefore above the letter. The difficulties of adapting a printing telegraph to such an alphabet are very great, and up to the present the only printing telegraphs in use in Japan are a few stock-tickers, including the Siemens and Halske Ferndrucker. The problem is very difficult but not insoluble. Instead of the 5-unit alphabet, the 6-unit alphabet, or some other corresponding lengthened alphabet or code of signals will be required. The 6-unit alphabet and a shift-key will give the required range of characters. Fortunately also the printing in vertical lines and reading the succession of lines from right to left can be provided for by inserting the message form in the typewriter in the usual way, but arranging the type to print horizontally instead of vertically, for instance, thus:—

NOW IS THE TIME
FOR ALL GOOD MEN

1741
9513
9156

Also it is obvious, when once we think about it, that the Arabic numerals can be added horizontally just as easily as vertically. We read figures horizontally and add them vertically. The Japanese read figures vertically and add them horizontally. For instance, they write the year 1910 thus:—

1
9
1
0

In the case of China there are at least several thousand ideographic characters required for ordinary intercourse and there is no alphabet. Telegraphy of any kind, to say nothing of printing telegraphy, would be impossible under such conditions, but by numbering the ideographs and by telegraphing the numbers, the difficulty is converted into one of coding and decoding at the sending and receiving stations. So far as telegraphy is concerned, under such circumstances only the ten numerals are needed, and an extremely simple printing telegraph with only ten numerals and one or two other characters, and using the four-unit alphabet with 16 permutations, will meet all requirements. Printing telegraph apparatus to meet these requirements will be cheap, simple, and very rapid and reliable.

Of course, the alphabet difficulty only arises in the case of a printing telegraph working on an international circuit connecting two countries speaking different languages. It is chiefly in Europe, with its great variety of important languages, that the trouble exists. A printing telegraph in Europe to be really international must meet the requirements of all the leading European languages. When an ocean intervenes, printing telegraph communication is impossible at present, and the problem of conformity to two different alphabets does not arise. By a printing telegraph to be used internationally is meant a printing telegraph like the Murray automatic or multiplex that can retransmit messages automatically from a received perforated tape. Obviously, for such retransmission to be possible all over Europe, an international keyboard must be employed applicable to all the nations of Europe. That is what the Murray systems have attempted to provide, as shown in Fig 1.

In the case of Great Britain, there are no accented letters, but there is a very curious alphabetical difficulty arising out of the similarity in the methods of writing shillings and pence and fractions. It is an insignificant little trifle, but it has caused much trouble to the British Telegraph Administration and serious loss to merchants. For instance, 7/8 is 7s. 8d. or the fraction $\frac{7}{8}$. The difficulty is to discover a method of avoiding the confusion. It does not occur in the case of countries not using British coinage, and international circuits between Great Britain and the Continent of Europe cannot conform to British requirements, as they are bound by the International Telegraph Convention, which provides for the use of the oblique stroke as the fraction sign and not as the shilling stroke. The Hughes, on which practically all British-Continental traffic is carried, represents fractions in this way, namely, 7/8. As an illustration of the confusion which exists, 3 7/8 may be read as 37s. 8d. or as $3\frac{7}{8}$. Also 37/1/2 may be 37s. $\frac{1}{2}$d. or £37 1s. 2d. To get over the difficulty, in the case of the Morse key and sounder a new Morse signal was introduced to indicate a break between the whole number and the fraction. This signal used to be two *M*'s — —   — — It is now — — — — This is liable to be confused with — — — — — which represents the cipher 0. Hence the fraction 3 7/8 is liable to become 307/8. Again, the new signal for the Morse oblique stroke is confusing. It used to be three *S*'s - - -   - - -   - - - Now it is - — - - — and is liable to be sent - — - - — which is *ex*, and the fraction becomes 307 *ex* 8.

The following is an actual case of error in a message from abroad. The group of figures was as follows: $2\frac{5}{16}$, $3\frac{1}{4}$, $4\frac{3}{8}$, $56\frac{1}{2}$. It was stated to be one group, and it was received thus: 25/1631/443/8561/2.

An actual case of loss arising from this confusion occurred in the case of the following message: "Buy at 1/2¼," the meaning being "Buy at one shilling and twopence one farthing." It was telegraphed, "Buy at 1/2 1/4." The addressee read it as meaning "Buy at 1s. 2d. to 1s. 4d.," and acted accordingly.

A neat way out of the difficulty in the case of the commoner fractions is the use of what is known as superior figures:—

$^1/ \quad ^3/ \quad ^5/ \quad ^7/ \quad ^9/$

These are printed as single characters, and are followed by an ordinary numeral or numerals for the denominator. Thus $^3/8$ is quite obviously a fraction and is distinct from 3/8, which is shillings and pence. It is useless, however, for Continental traffic.

Another suggestion was to use the oblique stroke for fractions, thus, 3/8, in accordance with the Continental practice, and to have a vertical stroke for shillings and pence, thus 3|8. This is a good plan, and it has been adopted by the British Post Office with the addition of a rather absurd fraction tie, thus ⌒. 3s. 8d. is therefore now printed 3|8 and 2s. 2¾d. is printed 2|2⌒3/4. This is certainly not clear to the average man, and it cannot be transmitted at all outside of Great Britain. The single quotation mark used in Norway for the same purpose is better. Also the vertical shilling stroke is liable to be shortened by wear or bad printing till it is liable to be confused with the figure 1. It is rather difficult to see why the Post Office should not insist on the use of the symbols £ s. d., which are universally understood. The only difficulty in the way seems to be the alteration in the count of the number of words. 3/8 counts as one word; 3s. 8d. counts as four words. This fraction difficulty exists even with the Morse key, but printing telegraphs accentuate it.

Printing telegraphs also using capital letters only, the S and D do not look so clear when printed in capitals, thus 3S. 8D.

Code and Cipher Messages.

A serious trouble in telegraphy is the handling of code and cipher messages. Code messages are usually understood to be those containing words apparently meaningless and having no apparent relation to each other, and cipher messages are usually understood to be messages composed of numerals with a secret meaning. In America the practice of contracting well-known words in transmission has come to be known as "coding." The word "code," however, is used here in its well-known international sense. Code messages are the usual form of commercial telegrams on long lines and cables, while Governments are fond of using cipher messages, usually in groups of five figures. An operator working on a keyboard can easily glance at an ordinary telegram and carry several words in his head while he is typing on the keyboard. With code and cipher messages this is not possible. This is obvious if we examine a fair average sample of a modern code message such as the following:—

"JYJEPLOLYG AYILUSTMA AVOKKOTUJ JYBOFOZNIT."

Clearly such messages must be very objectionable from a telegraphic point of view, as they impose much greater strain on the attention of the operators than ordinary comprehensible messages. There is, therefore, more liability to error on the part of the sending operator, and there is no context to enable the receiving operator to judge whether he is receiving sense or nonsense. The sending operator has also to work much more slowly with such messages. The cost of transmission is therefore higher. In the case of printing telegraphs code messages are also objectionable, because it is difficult to say, without some experience, whether such a telegram is a code message or a case where the printing mechanism has got out of unison. Fortunately the record made by printing telegraphs when they get out of unison is to a certain extent characteristic, and the fault can in most cases be recognised by an experienced operator.

Keyboards and Keyboard Operating.

With code and cipher messages it is absolutely essential that the operator shall keep his eyes fixed on the message all the time that he is sending, if he is to work rapidly and accurately. With the Morse key and sounder it is an easy matter for an operator to keep his eyes on the copy. With a typewriter keyboard, on the other hand, it would appear at first glance to be very difficult to work without looking at the keyboard. Experience has shown, however, that there is no real difficulty, and that in one month, with proper training, an operator can become an expert in "touch writing" on a typewriter keyboard. That is to say, he can learn within a month to operate rapidly and accurately on a typewriter keyboard without taking his eyes off the message. Code and cipher messages are then as easy to transmit on typewriter keyboards as on the Morse key, with the advantage that a single stroke on a key sends each character.

The same difficulty has been experienced in connection with the use of the ordinary typewriter in telegraphy, and also in using certain Morse transmitting keyboard machines. The typewriter companies long ago discovered the value of "typewriting by touch," and all the record breaking "typists" work in that way. Linotype operators have also discovered the advantage of this method of working. Some years ago it was noticed in New York newspaper offices that certain linotype operators (on piecework) were making considerably higher wages than their fellows. It was discovered that they had learned to operate the very large and complicated linotype keyboard of ninety characters without taking their eyes off the copy. Knowledge of the method soon spread, and "touch operating" on linotypes is now quite general.

Typewriter keyboards are much less formidable. On the piano, of course, playing by touch is essential, and it is much more difficult than on a typewriter. On the latter it is merely a question of systematic instruction and training on the lines long ago found necessary in piano playing.

After some months' practice in this way, operators become extremely rapid and accurate. The author has seen 101 successive average British messages of 20 words perforated on a keyboard without a solitary error, and that at the high speed of 90 messages an hour. This is over 2,000 words per hour of complicated matter with many figures and strange words and addresses and personal names. The operator had at the same time to sign the messages and number the perforated tape.

The best operators are those whose sending becomes purely mechanical. Some men will use the Morse key and talk to you at the same time without making a mistake in the message they are sending. Others can whistle a tune and keep time with the "sticks," while punching a message on the Wheatstone puncher, and the perforated message will be free from errors. Operators have been known to work for a whole day on the Morse key without making a single mistake. When this stage of automatic perfection has been reached the operator becomes valuable, especially in the case of printing telegraphs. Such skill reduces the number of errors and of corrections and inquiries, and it is these corrections and inquiries that reduce the output of a telegraph system so much. Every such correction or inquiry means a loss of time on the average equal to the time of transmitting half a message, and more in those cases where the sending operator has to stop to look up the previous message to answer the inquiry. As an illustration of how automatic the work of sending messages becomes, a case was mentioned in the *Telegraph Age* of an operator in an American telegraph office having received the news of Lincoln's assassination over his wire without noticing it. He wrote it out and the news was posted up outside the telegraph office. A great crowd assembled. The telegraph operators were surprised, and on inquiring what the crowd was about learnt that Lincoln was shot. The operator who had received the message, had received it mechanically, and had been entirely unconscious of the substance of the telegram he had written down. That sounds incredible, but it is no surprise to telegraph operators, and it is no surprise to highly skilled shorthand writers. It is exactly in accord with their own experience.

CONTRACTIONS.

With the Morse key an operator can use contractions in sending, because the receiving operator can easily write out the words fully on a typewriter. In the case of a printing telegraph this cannot be done, and if a word is sent over the line in a contracted form it will be printed in the same way. In America contractions are very

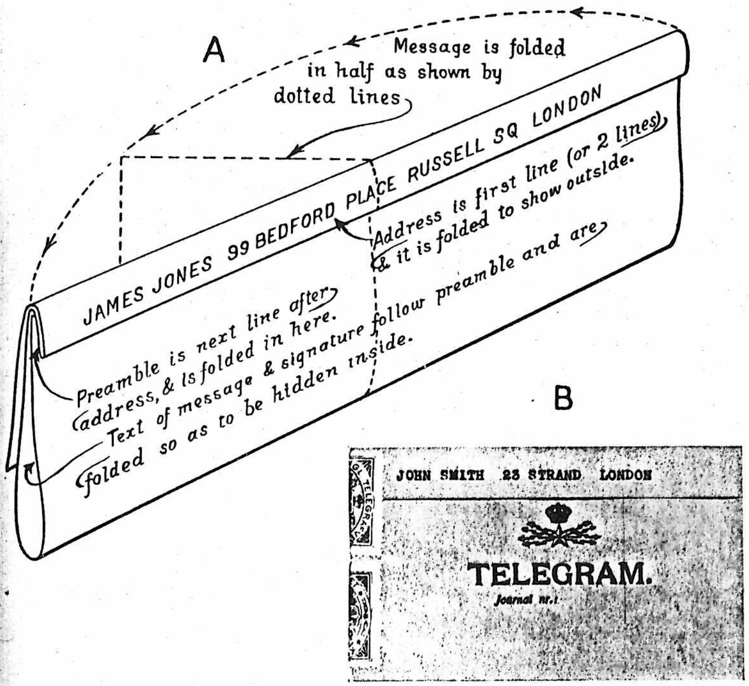

A
Message is folded in half as shown by dotted lines
JAMES JONES 99 BEDFORD PLACE RUSSELL SQ LONDON
Address is first line (or 2 lines) & it is folded to show outside.
Preamble is next line after address, & is folded in here.
Text of message & signature follow preamble and are folded so as to be hidden inside.
B
JOHN SMITH 23 STRAND LONDON
TELEGRAM.
Journal nr.1

FIG. 3.

A shows Murray Printing Telegraph method of folding telegrams so as to dispense with envelope **B** shows message completely folded and sealed with a couple of adhesive telegraph stamps used for this purpose only. The advantages are saving of cost of envelopes and saving of time and labour of addressing them.

freely used by operators, and these contractions have presented some slight difficulties to printing telegraph inventors in the United States. In Press messages contractions are also very freely used, and in Press messages to be sent over long ocean cables contractions have been developed into a fine art. All that a printing telegraph can do in such circumstances is to record the contractions.

ENVELOPES AND ADDRESSES.

On the Continent of Europe telegrams are not put in envelopes. They are folded and sealed and sent out in that way. In Germany the address has to be inserted in a special place in the middle of the top of the form. As the preamble comes before the address (in accordance with the terms of the International Telegraph Convention), the preamble has to be printed first, then the address, in Germany, above it, and afterwards the text below it. With a tape printing telegraph like the Hughes, it is easy to put the address at the top, or on the back as in France; but with a page printing telegraph, if it is to work automatically, there cannot be any turning back to put the address in the middle of the top of the message form, and it is quite impossible to print the address on the back as required in France. Fortunately, in the case of the Murray automatic system, as there is a receiving tape on which the message is recorded as perforations before it is printed, there is no difficulty in turning back by hand and printing the address where wanted, without interfering with the reception of the signals over the line. This is the arrangement adopted in Germany with the Murray automatic system, but there is undoubtedly loss of time when the automatic line and page feeds are not fully employed. In any case with a direct-printing page-printer turning back is not possible, and the message must be printed straight ahead as received. Page-printing saves time and labour; but the use of envelopes has a number of drawbacks. With the message folded so as to show the address only, as on the Continent, no envelope is needed, and therefore there is no loss of time and labour in addressing the envelopes, and there is no risk of error in copying the addresses on to the envelopes. Also the cost of envelopes is a considerable item. In Great Britain, for instance, 90 million envelopes are required for telegrams every year. Doing without envelopes would therefore save a considerable sum; but in Great Britain there are a large number of registered addresses, and these compel the writing out of the full address. In many cases, though, the more important registered addresses are printed ready on envelopes. The author devised a method of folding messages to suit page-printing telegraphs (see Fig. 3).

In this arrangement the address is transmitted first and then the preamble. This gets rid of any necessity to turn back, and the message can then be folded so as to show the address only. The conditions, however, are very complicated and in a case of this kind where there are so many conflicting considerations Government Departments are slow to move. Up to the present the new system of folding has not been used in England or Germany, but it is used in connection with the Murray automatic system in Russia, Sweden, and Norway. It is suitable for any page-printing telegraph, and it appears to be the only possible way of doing without an envelope in the case of messages received on a direct-printing page-printing telegraph.

Mechanical Difficulties.

This record of printing telegraph troubles may be conveniently brought to a close by some reference to the mechanical difficulties arising from the special mechanical problems that have to be solved by the inventors of printing telegraph machinery. Telegraph instruments belong to the class of controlling machines which are of necessity composed of locks, valves, and other ratchet mechanisms. These are the most unsatisfactory of all the kinematical elements, because they do not slide or roll; they strike. Also, their bad character is not improved by the facts that they have almost invariably to be operated by springs, that there is serious wear, and that there are numerous screws and pins which tend to work loose under the continual knocking and vibration inherent in such machines. The theoretical conditions are, in fact, so bad that the satisfactory service obtained from these machines is a matter of surprise. Success has been achieved as the result of attention to a number of practical details. One or two of the most important of these points may be conveniently illustrated by reference to the best known machine of this class, namely, the modern typewriter. A quarter of a century of experience has taught typewriter manufacturers the essentials for success. In the first place, it is a difficult thing to take a screw out of a modern typewriter. Quite a strong wrench with a screwdriver is needed. The screws have been driven absolutely tight home. The screws will also be found to fit well. There are no loose wobbly screws in a good modern typewriter. That is one essential point also in all telegraph machinery. Using only good fitting screws and driving them fast home are elementary and commonplace precautions, but printing telegraph inventors have suffered more from loose screws than from any other single mechanical defect. Another point to be noted about a modern typewriter is the generous size of the springs, and the avoidance of flat springs. Wherever possible steel piano wire springs are used in preference to any other kind. They are also made as large as possible, and there are no sharp bends in them. By using springs ample in size the strain put on them in working is far below their limit of elasticity, and springs are then as satisfactory as any other kind of mechanism. This also is an obvious and elementary point, but it is continually being disregarded by mechanics and inventors. There is also the question of the degree of accuracy required for various parts. Some parts have to fit finely to $\frac{1}{10000}$ of an inch, and other parts, on the other hand, must have

plenty of "air," as the Germans say. The fit must be quite loose. In printing telegraphs as much trouble has been caused by fits being too good as by their not being good enough. Only one other point need be considered. In consequence of their nature, ratchet mechanisms must wear rapidly if they come frequently into action, as they have to do in telegraph machines. The expression "ratchet mechanisms" is used here in the widest sense, to include not only ratchets and pawls, but also valves, electric contacts, and similar mechanisms. There are two remedies. The first is to make the striking surface as large as possible, and of the most refractory materials possible. The second remedy is to make the parts quickly interchangeable, and to provide plenty of cheap spare parts. In a typewriter, for instance, all the wearing parts are interchangeable, and new parts can be quickly and cheaply inserted.

So far as springs and screws are concerned, elementary precautions can be adopted from the outset, but it is not possible to say offhand which parts will wear well in a printing telegraph, and which will wear badly. Only prolonged trials in practical work can develop the weak points, and even when the weak points are known it is not practicable to provide the abundant and cheap supply of interchangeable spare parts until the apparatus has been standardised, and the apparatus cannot be safely standardised until it has been in use for at least two or three years. That puts the printing telegraph inventor in a very difficult position, and it explains why it takes years to develop a printing telegraph up to the stage of practical commercial success. No doubt the telegraph engineer of the future will be able to sit down and design and calculate out a printing telegraph complete and perfect in every detail for any given purpose, just as engineers now design steam engines or electric motors, but it will be a good many years yet before the art of printing telegraphy reaches that degree of perfection.

PART III.

The Murray Printing Telegraph Systems.

In order to illustrate some methods by which the foregoing difficulties have been more or less overcome, the following account is given of the Murray printing telegraph systems. The Murray automatic system has already been described in the paper on "Setting Type by Telegraph,"[*] and a brief reference only will therefore be made to it, most attention being devoted to the new Murray multiplex page-printing telegraph, of which no description has yet been published.

It may be explained, in the first place, that the Murray printing telegraph systems form a complete printing telegraph organisation and that they comprise—

---

[*] *Journal of the Institution of Electrical Engineers*, vol. 24, p. 555, 1905.

The Murray Automatic Page-printing Telegraph, and The Murray Multiplex Page-printing Telegraph.

The two systems, the Murray automatic and the Murray multiplex, have been designed to work together as one whole, the automatic system being best suited for long lines, and the multiplex for lines of average length. The two systems are in a sense complementary to each other. Many of the instruments are the same in both systems, and are interchangeable, the same alphabet or code of signals—the 5-unit Baudot—is used in both, and the perforated tape is the same in both systems, so that a perforated tape message may be transmitted either over a Murray automatic or a Murray multiplex circuit, and it may be reproduced and retransmitted at the receiving station on either system. An important point is that the same keyboard perforator is used on both systems. The standard typewriter arrangement of the keys is followed on the keyboard, and the same characters are used in both systems.

In the Murray automatic system, the messages are first perforated on a strip of paper tape in the Baudot 5-unit alphabet. The perforated tape is then used to transmit the messages by means of an automatic transmitter working on the principle of the Jacquard loom. The speed of transmission of the signals is from 100 to 180 words (600 to 1,080 letters) a minute, and at the receiving station the arriving signals are recorded at the same speed as perforations in a second paper tape, which is an exact replica of the transmitting tape. This reproduced tape at the receiving station then serves to operate an automatic typewriter somewhat on the principle of a mechanical piano. The telegraph line is worked duplex, giving one transmission in each direction simultaneously on the one wire. The received messages are printed in Roman type in page form, at speeds ranging up to about 200 words a minute (20 letters a second). The keyboard perforator for preparing the transmitting tape was described and illustrated in the paper already referred to. The automatic transmitter and the receiving perforator were also described, and there has been no substantial alteration in the construction of these instruments, although there have been many improvements in detail. In the automatic printer a great improvement has been made by the construction of a high-speed typewriter specially designed by the inventor of the system to suit the automatic selecting mechanism. The essential feature of this typewriter is that the typebars are very short, only 2 in. long (50 mm.) from the pivot to the type. This ensures extremely high speed. It is the shortest typebar ever put into a typewriter, the average length of typebars in typewriters being from 3 to 4 in. (75 to 100 mm.). As the moment of inertia varies as the cube of the length of the typebars, the gain in speed with typebars only 2 in. long is from 3 to 8 times. The typebars are also provided with ball-bearings, to ensure free movement and permanent alignment. The illustration in Fig. 4 shows one of these typebars full size. The typebars being so short, it was necessary to arrange them in a complete circle in order to get room for the required number of 51 characters. As it was very desirable that the operator should be able to see the printing as it proceeded, the circle of type had to be arranged in a vertical plane. Key levers were omitted, as the inertia of key levers interferes with high speed. There are no other special features beyond the fact that the machine is built with unusual strength to stand the strain of the high speed. Fig. 5 is a front elevation of the complete printer, the upper part being the new special typewriter.

Fig. 6 is a back view of the printer.

In a typewriter, or in a page-printing telegraph, there are four motions of the paper as follows:—

Letter-feed.—Short horizontal movement (one letter).
Line-feed.—Long horizontal movement (about 60 to 70 letters).
Column-feed.—Short vertical movement (one line).
Page-feed.—Long vertical movement (one page or message form).

In the Murray automatic printer, the letter, line, and column feeds are entirely automatic, but the page-feed is manually operated, this having been found sufficient for present requirements. The maximum speed that has been reached on this printer is 250 words a minute (25 letters per second). The speed might perhaps be pushed up to 300 words a minute (30 letters per second), but the wear and tear would probably be great at speeds exceeding 200 words a minute. Typewriter companies often claim very high speeds for their machines, but it may be accepted as a fact proved by experience that no hand-operated typewriter on the market to-day will continue to do satisfactory work at a speed greater than 120 words a minute (12 letters per second), and for most typewriters the limit may be taken as 100 words a minute.

In order to prevent interruption of traffic by any stoppage of the apparatus, it is necessary to have reserve machines. With an automatic system this means duplicating the whole of the apparatus. The result is that the Murray automatic system is very expensive, costing at present about £1,200 per circuit, exclusive of royalties. This is a very serious handicap on the use of the Murray automatic. If manufactured in large quantities the cost would come down to about half this amount, but under present telegraph conditions the field for a printing telegraph of this kind is not sufficiently large to require large quantities of the apparatus.

Taking the four factors already referred to, namely, saving of time, labour, line, and office equipment, the Murray automatic system shows to advantage only in respect of saving of line. The cost of office equipment is greater than with the Murray multiplex, there is less saving of labour than with the multiplex, and there may be loss of time if the working arrangements are not good. This is specially the case if the system is worked at a high speed to carry heavy traffic. The working organisation in this case must be first-class, or there will be a great reduction in the carrying capacity of the system. On long lines, 1,000 miles and over, the saving of time and labour are of much less importance than increase in the carrying capacity of the line, provided always that telegraph traffic is growing rapidly so as to render increase of carrying capacity important. This is the case, for instance, in Russia and other new countries (Russia is practically a new country, Asiatic Russia, at any rate). It is in such conditions that the Murray automatic has decided advantages, as follows:—

1. The alphabet or code of signals that it employs, and the manner of employing it, result in less signalling time per letter than in the case of any other system. The ratio is approximately 5 for the Murray automatic compared with 6 for the Murray and the Baudot multiplex systems, and 8 for the Morse alphabet. This is an advantage of 20 per cent. over the multiplex—an important matter on a long line. The advantage over the Morse alphabet is about 60 per cent.

2. Synchronism is not employed, only isochronism. That is to say, phase is of no importance, but the speed must be right.

3. Governing or control of speed is very quick, so that the right speed is obtained in half a second, and is re-established in half a second if it is momentarily thrown out by a line disturbance.

4. The Murray automatic apparatus is simple—much simpler than any multiplex system.

5. It works very well through the simplest of all repeating stations, namely, the Wheatstone duplex.

6. It works very well and easily with the duplex balance, even on very long lines.

As an illustration of the last point, it may be mentioned that the Murray automatic system is being worked duplex between St. Petersburg and Omsk in Siberia, with three Wheatstone duplex repeating stations at Riazan, Samara, and Tscheliabinsk. The total length of the line from St. Petersburg to Omsk is 2,224 miles (3,550 kilometres). The wire is iron, and the working speed with the Murray automatic is about 56 to 60 words (336 to 360 letters) per minute. The Wheatstone speed on this line is less than 40 words (240 letters) per minute. Of course, on such a long line there are periods when it is only possible to work simplex, but that duplex working should be commercially practicable on such a circuit is remarkable. Obviously on such a line, with growing telegraph traffic, the one pressing question is increase of the carrying capacity of the line. Saving of time, labour, and office equipment are quite subsidiary.

It will be noticed also that the advantages just enumerated are chiefly advantages for working over long lines. Hardly any of them are of importance on short lines. On lines of moderate length, time and labour saving are the all-important factors, and line saving is quite subordinate. On such lines no automatic system can save so much time and labour as a multiplex system. The splitting up of the line into from four to eight channels greatly facilitates the handling of traffic. There is less delay on messages, while inquiries and corrections are quickly obtained because of the numerous channels over which inquiries can be made. The speed of each channel being comparative low, one operator on each sending channel can perforate, tape, and attend to his own automatic transmitter. That saves labour compared with the automatic system. Also at the receiving end of the line, the speed of each channel being low, 30 to 50 words a minute, the printers can print direct, and can be made entirely automatic in their actions, thereby saving labour, because one receiving operator can then receive and check as many as 150 messages an hour. On the other hand, on a long line it is not possible to get a number of multiplex channels. Hence on long lines the multiplex loses its chief advantage over the automatic system, and the advantages of the automatic system, already mentioned, then predominate.

On lines not too long to prevent a number of channels being obtained with a multiplex system on one line, the multiplex has the advantage that it can give simultaneous independent channels of communication between several towns connected by a single telegraph wire. This is an arrangement of great practical importance in the case of several towns, none of which alone can keep a telegraph line fully occupied. With an automatic system such an arrangement is not possible. With the automatic system messages may be retransmitted automatically by the received tape, so that various centres can be connected up in this way on one line, but this would only be practicable on long lines connecting important centres. The Murray multiplex, however, now possesses this advantage of being able to retransmit messages from perforated receiving tape.

THE MURRAY MULTIPLEX PAGE-PRINTING TELEGRAPH.

Although the relative advantages and disadvantages of automatic and multiplex printing telegraphs appear to be obvious and are now tolerably familiar to telegraph engineers, this knowledge has only been gradually accumulated during the past few years as the result of prolonged trials of various automatic and multiplex printing telegraphs. The British and German Administrations especially have carried out a very large amount of experimental work with various telegraph systems, including the Murray automatic. The idea of combining the advantages of the automatic and multiplex systems led to the development of the Murray multiplex printing telegraph. It is only about a year since this system passed out of the laboratory stage and arrived at practical success. The Murray automatic system may be said to be based on the Wheatstone automatic transmitter. The Murray automatic transmitter is greatly modified, but the essential principles of the Wheatstone transmitter are embodied in it. In a multiplex system the instrument corresponding to the Wheatstone automatic transmitter is the distributor, and the Murray multiplex system may similarly be said to be founded on the Baudot, because it has taken the Baudot distributor as its basis. For driving the distributors, however, instead of the Baudot arrangement, the Delany multiplex plan of using the Lacour phonic wheel motor is adopted. Apart from the distributors, the only resemblance between the Baudot and the Murray multiplex is in general principles and in the use of the Baudot alphabet. The Murray multiplex transmitting and printing machines closely resemble the corresponding Murray automatic instruments. Many are indeed identical. The normal speed of the Baudot is 30 words a minute for each transmission. In the Murray multiplex the speed is raised to 40 words a minute, in order to increase the efficiency of the labour at both ends of the line. It is possible that under certain conditions it may prove advantageous to increase the speed still further to 45 or 50 or even 60 words a minute. There are considerable possibilities of both capital and labour saving by such increased speed, and the Murray multiplex has the advantage of easy adjustment of speed over a considerable range from 20 up to 45, and possibly 60 or more words a minute for each transmission or channel.

Like the Baudot and similar systems, the Murray multiplex printing telegraph divides up the line time so as to give several transmissions or channels on one telegraph wire, each at a comparatively low speed suitable for the work of one operator sending and one receiving. Two distributors, identical in design, are employed, one at each end of the telegraph line (station A and station B). The distributor at station A sends out a governing impulse once for each revolution of the contact arm (four revolutions per second for 40 words a minute). This impulse controls the speed and phase of the distributor at station B so as to keep it running in synchronism with the distributor at station A. The distributor used in the Murray multiplex is shown in Fig. 7. This instrument is a "double," giving two simultaneous transmissions working simplex and four when working duplex. The new system may also be worked "triple" or "quadruple," the duplex balance in these cases giving 6 or 8 transmissions simultaneously on one line. Special arrangements have been designed to give up to 6 transmissions in each direction, but it seems unlikely that anything more than quadruple duplex (8 transmissions) will ever be required in practice.

The distributor brush arms are carried directly on the spindle of a phonic wheel motor, which is identical in all respects with the phonic wheel motor employed in the Murray automatic system, and it is driven in the same way by a vibrating reed. There are no gearwheels or governing mechanisms. The commutator and contact arms and brushes are the same as in the Baudot, and the adjustments are the same. The distributor fits on to a wooden base provided with spring contact terminals, so that the machine may be instantly lifted off or replaced. This distributor will work perfectly in conjunction with Baudot distributors and other Baudot apparatus. It has the advantage over the Baudot of being simpler, cheaper, and easier to construct. On the other hand, where Baudot distributors are already in use, the Murray

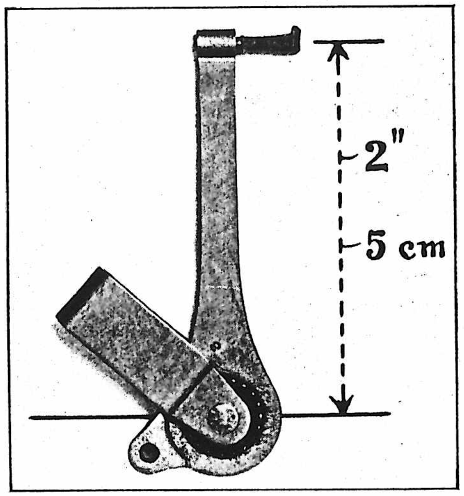


FIG. 4.—Typebar from Murray Automatic High-speed Printer. It is exceptionally short and has ball bearings.

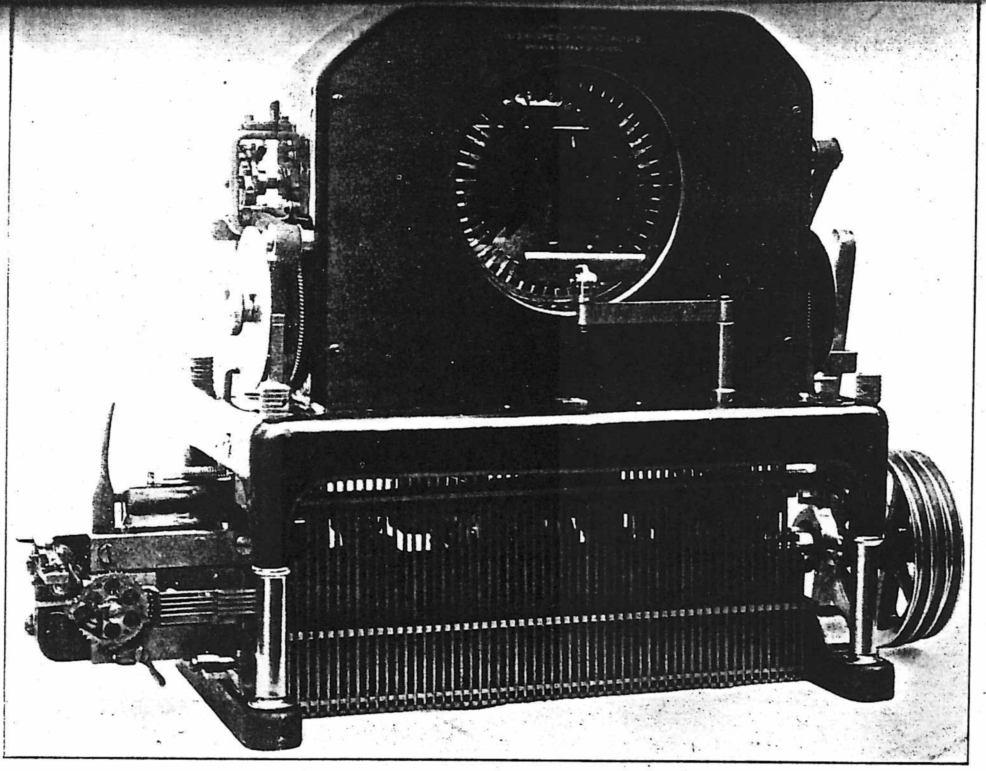


FIG 5.—Front View of the Murray Automatic Printer fitted with the Murray High-speed Typewriter.
Speed 1,200 letters per minute.

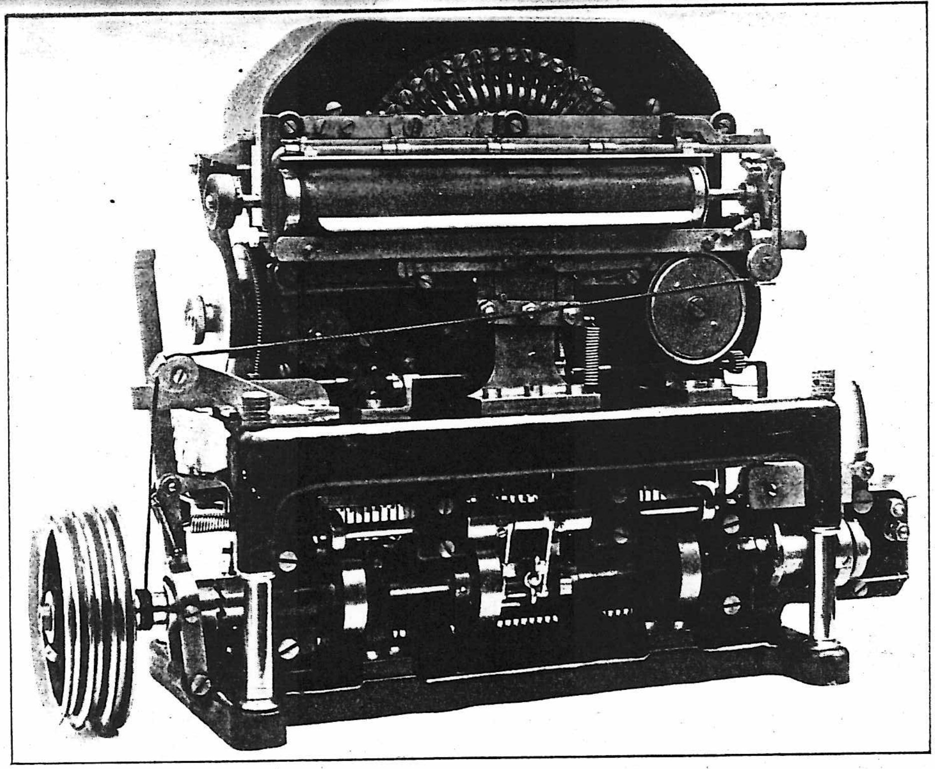


FIG. 6.—Back View of the Murray Automatic Printer with High-speed Typewriter.

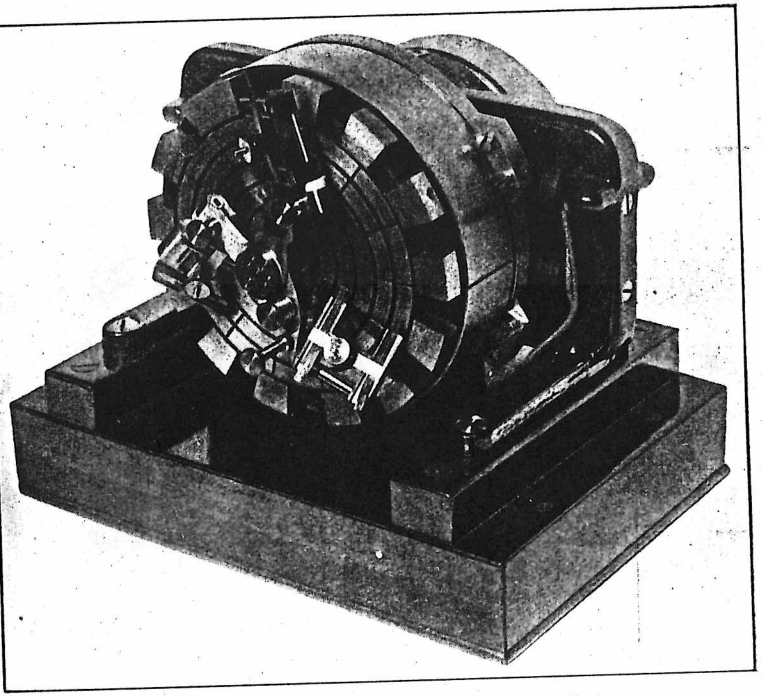


FIG. 7.—Front View of Murray Multiplex Distributor.

multiplex transmitting and printing mechanisms will work excellently with the Baudot distributors. It will be noticed that the Baudot commutator and revolving brush arms take the place of the automatic

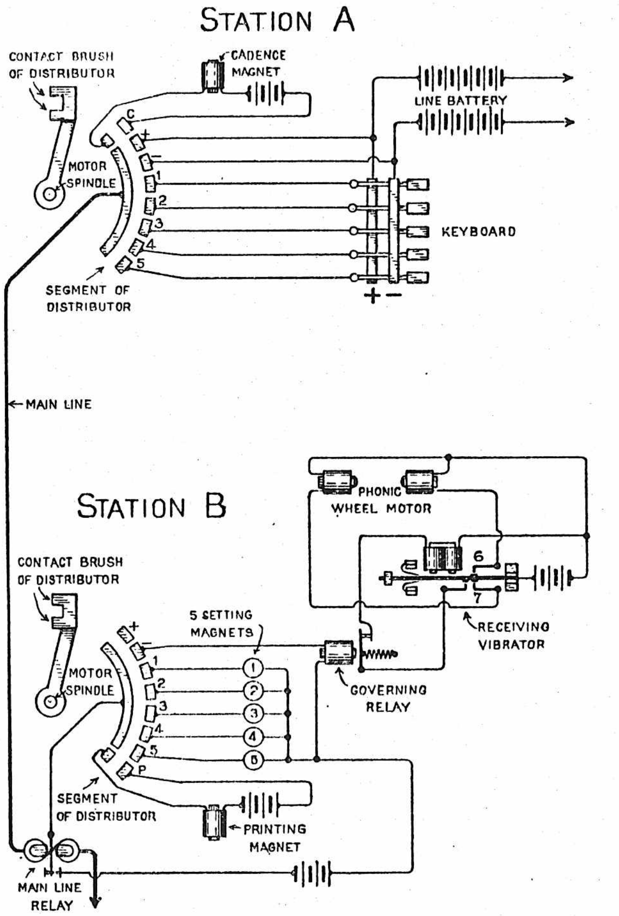


FIG. 8.—Theoretical Diagram of Murray Multiplex.

transmitter driven by the same phonic wheel motor in the Murray automatic system. The Murray multiplex, in fact, combines many features of the Murray automatic and of the Baudot, and a considerable portion of the apparatus, with slight modifications, is interchangeable in all three systems.

The theoretical arrangement of the electrical connections in the Murray multiplex is shown in Fig. 8.

One of the transmitting channels or segments of the distributor and revolving contact brush are shown at each station. For the sake of clearness the other segments for the other transmissions on the same telegraph line are omitted, and for the sake of simplicity the Baudot 5-key transmitter is shown at station A. Also at station A the vibrator and phonic wheel that keep the contact brush of the distributor revolving are omitted. The five transmitting keys at station A normally rest against the top contact bar, which is connected to the negative end of a split battery. The depression of any key breaks contact with the negative bar and puts the key into contact with the positive battery bar. The keys are connected to the contact blocks 1, 2, 3, 4, 5 of the distributor. Various permutations of five positive and negative impulses are transmitted into the line as the distributor arm revolves. In the Baudot system the sending operator has to learn to manipulate these five keys in the 31 different permutations required, and he has to depress the keys at regular intervals, determined by the cadence magnet which is operated by the distributor three times a second, the normal speed of the Baudot being 30 words a minute for each transmission. This method of transmission has the advantage of simplicity of mechanism, but it requires special skill and training on the part of the operator, the work is very monotonous, and the speed is limited to about 30 words a minute.

A typewriter keyboard mechanism to operate these five contacts can be easily designed. Such a machine made by the writer for use with the Murray multiplex is shown in Fig. 9. The five contacts corresponding to the five keys in the diagram, Fig. 8, may be seen on the left of the instrument. There is also a cadence magnet on the left which locks and unlocks the keys to enable them to be depressed at the right moment. On the right there is a letter-counting magnet, which rings a bell at the end of each line of about 60 letters. This is a first-class instrument of its kind, simple, strong, and cheap to make; but as the result of careful practical trials by the British Post Office, automatic tape transmission was found to be so much superior to direct transmission that direct transmission was abandoned altogether, so far as the Murray multiplex is concerned.

Actual trial between London and Birmingham for several weeks showed the advantages of automatic tape transmission over direct transmission to be as follows:—

1. The output of messages per operator per hour is practically doubled as compared with direct transmission.

2. There is less nerve strain on the sending operators, because there is no cadence to be observed.

3. Much more skill is required to work on the direct cadence keyboard than on the keyboard perforator. This has been proved conclusively by practical trials.

4. Provision is made for quick and invisible correction of errors

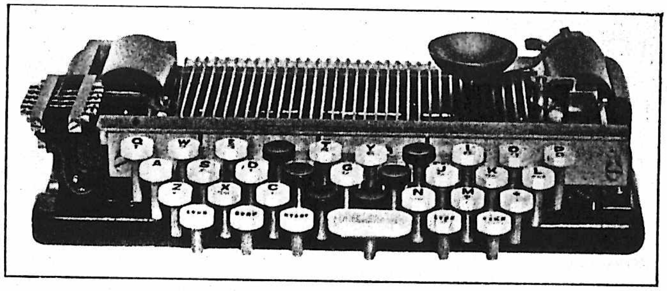


FIG. 9.—Direct Keyboard Transmitter for Murray Multiplex.

LTRS STOP START

LINE FIGS

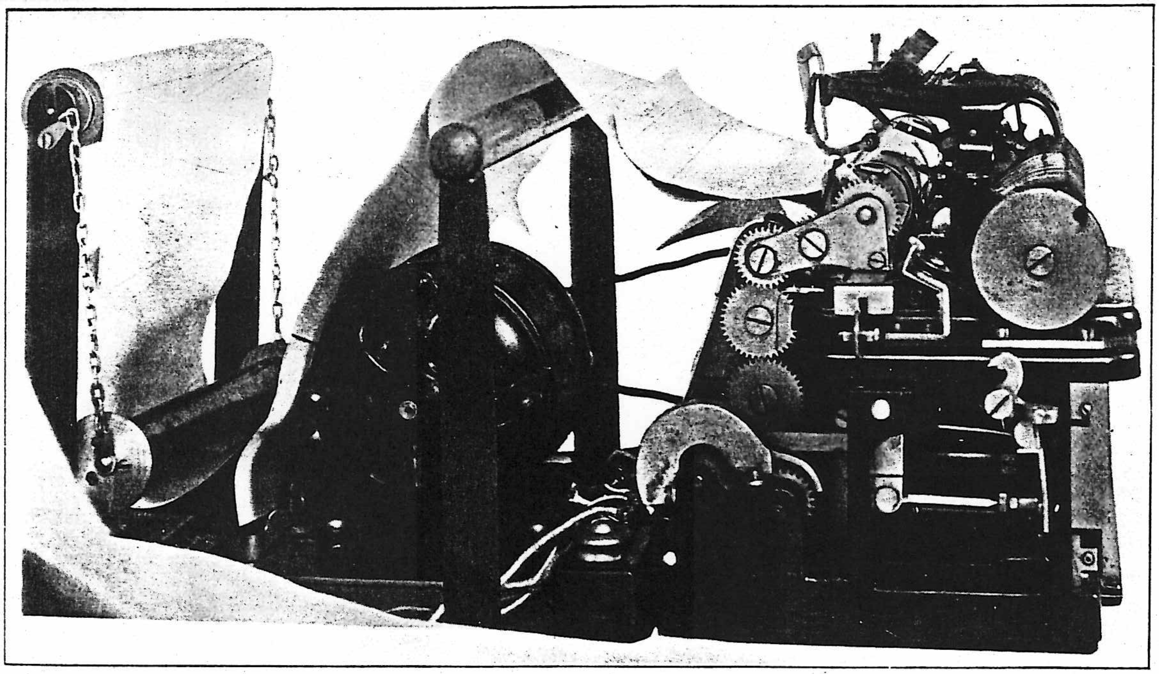


FIG. 11.—Murray Multiplex Printer. Side View.

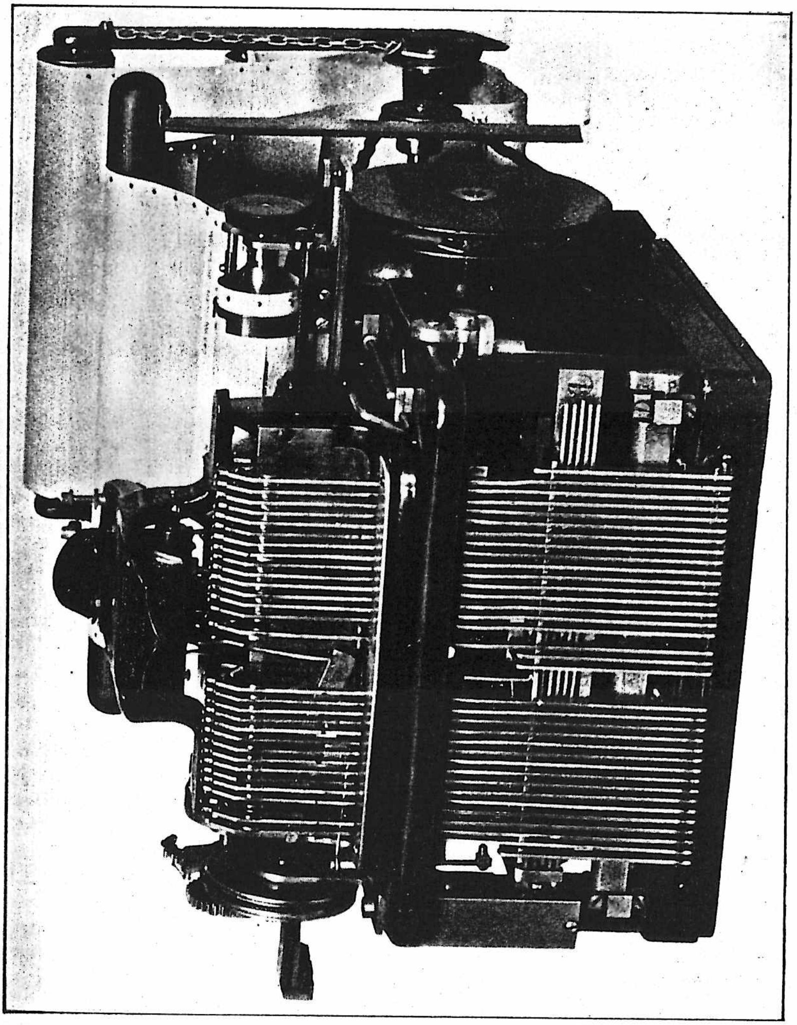


FIG. 12.—Murray Multiplex Printer. Front View.

before transmission in the case of the indirect method of tape transmission in the Murray multiplex. Practical experience has shown that this is a valuable feature with page-printing. With direct transmission all errors appear in the printed message. Also errors are more numerous with direct than with tape transmission, operators being able to do more accurate work on the free keyboard of a keyboard perforator, compared with a direct transmitting cadence keyboard.

The trials were made at 40 words a minute instead of the normal Baudot speed of 30 words a minute, the increased speed being one of the advantages gained by the use of a typewriter keyboard.

The instruments used in the Murray multiplex for tape transmission are shown in Fig. 10.

On the right at A is a keyboard perforator identical with that used in the Murray automatic system. The tape passes from the perforator into an automatic transmitter B. This automatic transmitter is the same as the tape-feeding mechanism of the Murray automatic printer, except that the tape-feeding mechanism is driven in this case by a magnet instead of by a cam. The magnet is operated at regular intervals—four times a second—by the cadence contact on the distributor. This is equivalent to a speed of 40 words a minute.

After running through the automatic transmitter the tape passes on to an automatic tape-winder C. This instrument is of a very simple character and is entirely automatic. Both sides of the tape may be used, so that the cost of the tape is small. The tape also forms a complete "home record" of what the operator has sent. It is neatly wound up without labour cost, and there is no mess of tape on the floor. There is one of these automatic transmitters for each sending operator, so that an extra transmitter attendant is not necessary.

As the automatic transmitter runs steadily at 40 words per minute, it may at times overtake the operator. A starting and stopping lever is therefore provided on the automatic transmitter shown at S. This is arranged with a locking mechanism so that the operator can only start or stop the transmitter at the right moment. There is therefore no danger of interrupting a letter signal in the act of transmission, thereby causing a wrong letter to be transmitted. In this way the operator has complete control over the tape. He can start or stop transmission at will. He can pull back the tape and repeat a message. He can correct errors instantly and invisibly. He has a perfectly free and extremely rapid typewriter keyboard, which he can operate as fast or as slow as he pleases. Only typewriter skill is required, and there is no cadence to be observed.

It is to be noted that it is possible to make a much simpler tape transmitter than that shown in Fig. 10 if the perforations in the tape are arranged crossways, but in that case the tape would not be interchangeable on the Murray multiplex and the Murray automatic systems. At present the tape is identical for the two systems, and it appears desirable to preserve this identity, even at the cost of a little greater complexity in the mechanism of the transmitter.

It will be noticed that tape transmission involves considerable increase in capital cost compared with direct transmission, and it also involves cost for paper tape, but the saving in line and labour is so great that it far outweighs the increased expenditure. Also, if a perforator and tape transmission are not used, then a printer has to be available to enable the operator to see what he is sending out—that is, to supply a "home record." With tape transmission the tape serves as the "home record." The cost of the perforator and transmitter are therefore about balanced by the cost of a printer.

One disadvantage of tape transmission is that a rapid operator may go on perforating until he is several messages ahead of the transmitter. An inquiry may then come through from the other station, and the operator cannot transmit his answer until the messages already perforated have been transmitted. This may take two or three minutes, and it would delay delivery of a message at the other station. An arrangement has accordingly been designed, by throwing over a switch, to convert the keyboard perforator temporarily into a direct transmitter. The tape transmitter is switched out, and the punching magnet of the perforator becomes a cadence magnet. Five contacts are provided on the perforator to be operated directly by the keys. Although direct transmission is not so good as tape transmission, there is no objection to its use for sending a few words of reply to an inquiry. As soon as the reply is transmitted the switch is thrown over again and tape transmission is resumed at the point where it was stopped. The printing mechanism at the other station for recording this temporary direct transmission will be described presently. This arrangement enables direct and instant reply to be made to an inquiry, but it is doubtful whether it would be required in all cases.

Returning to Fig. 8, it will be noticed that there are two contacts on the distributor at station A which are connected direct to the plus and minus poles of the battery. A positive and a negative impulse are therefore sent into the line with each revolution of the contact brushes. This is the governing impulse which controls the speed of the distributor at station B. The method of governing is similar to that employed in the Murray automatic system. The receiving vibrator at station B is identical with the receiving vibrator in the automatic system. It is provided with buffer springs so that the speed of the vibrating reed varies with the variation of the electric current driving the reed. The contacts 6 and 7 on the receiving vibrator, instead of operating a receiving perforator as in the automatic system, energise the two magnets of the phonic wheel-motor driving the contact brushes of the distributor at station B. Varying the speed of the reed will therefore vary the speed of rotation of the distributor contact brushes. Let us assume that the contact brushes at the two stations are revolving at the same speed and that they are in phase with each other. Then, when the brush at station A is on the plus contact of the distributor the brush at station B will be on the positive contact of the distributor at station B. A positive impulse will flow into the line at station A and

will operate the main line relay at station B, closing the relay contact; but there will be no local action in consequence of this at station B, because the plus contact on the distributor is an idle contact with no connection. It will be seen that there is a local battery and a circuit passing through a local relay described as the governing relay. When the two brushes at the two stations reach the two negative contacts on the two distributors the main line relay contact will be opened, and there will be no local action at station B. If now the vibrator at station B is adjusted to run 1 or 2 per cent. faster than the vibrator at station A, then the rotating brush of the distributor at station B will run 1 or 2 per cent. faster than the brush at station A. Hence when the brush at station A is on the plus contact, so that the main line relay contact at station B is closed, the brush of the distributor at station B will have reached the minus contact. The result will be that the local circuit through the governing relay already referred to will be closed, and consequently the governing relay contact will be momentarily opened. This contact is in the same local circuit as the contact that drives the vibrating reed. The opening of the governing relay contact will therefore momentarily reduce the amount of current driving the reed. This will slow down the rate of vibration of the reed and thus reduce the speed of rotation of the distributor brush at station B. In this way the governing impulse from station A will repeat its retarding influence four times a second on the brush at station B. In this way the two brushes at stations A and B are kept not only at the same speed but also in phase, so that when the brush at station A touches successively contacts 1, 2, 3, 4, 5, the brush at station B will also be touching successively contacts 1, 2, 3, 4, 5 on the distributor at station B. Any permutation of signals sent out from the keyboard at station A will therefore be exactly reproduced in the five setting magnets of the printer at station B.

The printer, of which there is one for each channel or transmission of the multiplex, is shown in Figs. 11, 12, 13, 14, and 15; 11 is a side elevation, 12 is a front elevation. 13 is a sectional side elevation, 14 is a plan of the selecting mechanism with the typewriter removed; and 15 is a plan of one of the 5 setting magnets and the comb that it controls. The printer is driven by a small $\frac{1}{16}$-H.P. motor, as shown in Fig. 11. As the printer will print correctly as long as it is driven faster than the distributor, there is no need for synchronism between the printer and distributor, the former being arranged to run anywhere about 20 or 30 per cent. faster than the latter. The Blickensderfer typewriter is employed, and the message forms are fed in automatically from a roll made up in a rather unusual way. The message forms are perforated along each side like a cinematograph film, so as to gear on to sprocket pins on each ends of the typewriter platen. The message forms, in addition to being perforated along the edges, are lightly pasted together so as to overlap and at the same time form a continuous band, which is wound into a roll. The perforations ensure positive column and page-feed, and the overlap of the message forms renders it very easy to pull the messages apart after they are printed. The printer attendant has merely to pull off the messages one by one as they are finished. This involves an absolute minimum of thought and labour, and he can devote all his attention to checking the messages,

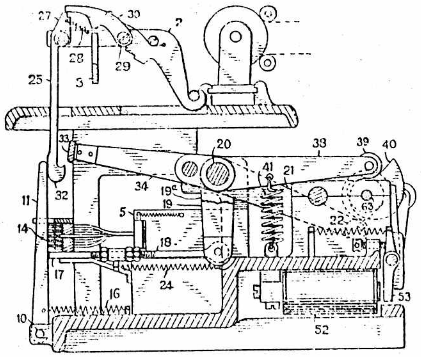


FIG. 13.—Murray Multiplex Printer: Sectional Elevation.

The result is that the receiving operator, when everything is running well, can check up to 150 messages an hour.

In the diagram Fig. 8, at station B there are five small setting magnets, 1, 2, 3, 4, 5. These are in the printer, and they record the signals transmitted from station A. A plan view of one of these five setting magnets of the printer is shown in Fig. 15: 5 is the magnet coil, 72 is the yoke, and 49 is the armature, pivoted at 48 and retracted by the spring 76 against the backstop 74. At the free end of the armature there is pivoted a pawl 75, which passes through a slot 71 in the frame of the machine. Resting against this frame are five differentially slotted "combs," or metal strips, lying side by side. One is shown at 14. Each of the five setting magnets controls one of the five combs, the pawl 75 of each magnet engaging in a nick on the inner edge of its corresponding comb. Five springs 73 tend to move each comb $\frac{1}{16}$ in. (1·6 mm.) to the left. When a signal energises one or more of the five setting magnets, the armatures are attracted and the pawls 75 are pulled back out of the way of the combs, which then move suddenly to the left in the direction of the arrow 83, under the action of their springs 73. In this way any given signal is stored up in the printer. Referring to Figs. 13 and 14, the five combs are shown in section at 14 in Fig. 13, and the top comb is seen in plan at 14 in Fig 14.

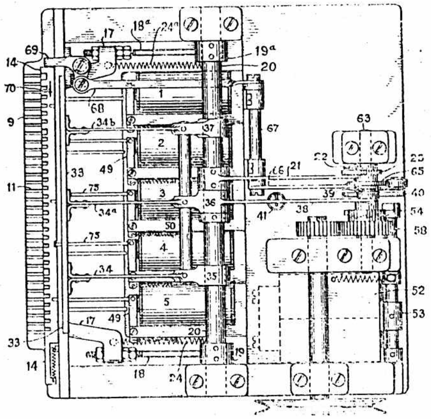


FIG. 14. Murray Multiplex Printer: Plan View with Typewriter removed.

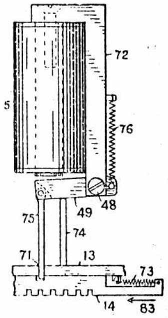


FIG. 15.—Plan of Setting Magnet.

Pivoted at 10 and crossing the combs at right angles are a series of about 30 latches or crossbars 11. These are held just clear of the combs by the supporting bar 17. Underneath the printer is a printing magnet 52. Referring to the diagram Fig. 8, it will be seen that this printing magnet is energised by the brush arm of the distributor closing a local battery circuit through the printing magnet immediately after the setting magnets have set the combs in some particular permutation representing a particular letter. In practice the printing contact is placed on an inner ring of the distributor, but for the sake of simplicity it is shown in the theoretical diagram in the same ring as the letter-setting contacts. The printing magnet, being energised, attracts its armature 53, which moves out the pawl 54, Fig. 14, thereby tripping a single-revolution clutch. This clutch, on being tripped, connects a constantly running pinion 58 (driven by the $\frac{1}{16}$-H.P. motor) with a cam spindle 63, carrying a battery of three cams. The clutch on being tripped causes the cam spindle to make one complete revolution, the clutch being then thrown out ready for the next printing impulse.

Referring to Figs. 13 and 14, it will be seen that the supporting bar 17 is carried at both ends by two connecting rods 18 and 18*a*, connected to two vertical levers 19 and 19*a*. These levers are pinned to the shaft 20. Pinned to the same shaft is a lever 21 with a cam roller 22. This engages with cam 23, Fig. 14. At the right moment, just after the combs have been set by the setting magnets 1, 2, 3, 4, 5, the cam 23 (set in motion by the printing magnet) allows the lever 21 to rise slightly, thereby pulling in the supporting bar 17 by means of the springs 24 and 24*a*. This allows the crossbars 11 to rest against the combs, the crossbars being pulled inwards by springs 16, Fig. 13. For any given signal only one group of slots will be in alignment across the five combs, and into this group of aligned slots in the combs one particular crossbar drops forward and throws the hook 32 of the hook lever 25 under the universal striking bar 33. These hook levers swing on a pivot on each typewriter key lever 2. The top of the hook lever 27 is prolonged into a catch. On each key lever 2 there is pivoted at 29 a pawl 30. The free end of this pawl rests normally on top of the catch 27 of the hook levers 25. When any given lever 25 is swung inwards by a crossbar, the pawl 30 drops down at the back of the catch on top of the hook lever 25 and holds the hook in the inward position under the striker bar. The letter signal from the distant station has thus been transferred from the magnets to the combs, from the combs to the crossbars, and from the crossbars to one of the hook levers 25 hanging on a particular key of the typewriter.

The striker bar 33 is carried on the end of three levers 34, 34*a*, 34*b*. These levers are braced into one frame by being pinned to the shaft 50, and they are free to oscillate on the shaft 20 by their hubs 35, 36, 37. From the central hub 36 there extends a lever 38 with the cam roller 39, which is operated by the snail cam 40 on the cam spindle 63. At the right moment this cam raises the lever 38 and depresses the striker bar 33, the striker bar frame oscillating on shaft 20, Fig. 13. The striker bar in its descent engages with the selected hook 32, thereby depressing key lever 2 and printing the corresponding letter on the typewriter. As the key lever 2 descends, the pawl 30 strikes the slotted bar 3 and is thrown out of engagement with the hook lever 25, which is then free to be restored to its normal outward positions by the spring 28 as soon as it is free from the striker bar 33, which is restored to its upper position at the end of each stroke by the spring 41.

The moment a crossbar has thrown a particular hook lever 25 forward into locked position, the supporting bar cam 23, Fig. 14, thrusts the supporting bar 17 forward so as to push out the crossbars, thereby freeing the combs. The moment this happens the combs are restored to their zero position by a third cam 65 on the cam spindle. This cam by means of a chain of levers and shafts, 66, 67, and 68, causes lever 69 at the end of the combs to thrust the combs back in the direction of the arrow 70 to zero position, where they are instantly caught and retained by the magnet armature pawls 75. It will be seen on studying this chain of mechanisms, that the combs can be and are restored to zero position before the depression of hook 32—that is to say, before the printing commences. The result of this is that the setting of the next letter signal by the setting magnets can proceed simultaneously with the printing of the last selected letter. These actions being simultaneous, a more moderate rate of operation is possible for the same speed than would be possible if the actions were successive. This considerably reduces the noise and wear of the mechanism.

The printing does not require description, as any ordinary typewriter action, such as that of the Blickensderfer, answers the purpose.

The line and column feeds of the message form are effected in the same way as in the Murray automatic printer. There is a clutch, which is tripped at the right moment so as to connect with the driving power. This winds up a cord, which pulls the typewriter carriage back to the beginning of the line (line feed), and at the same time turns it up to a new line (column feed). The typewriter carriage itself throws out the clutch when it reaches the beginning of the new line. This action is extremely simple and rapid, and gives no trouble. The typewriter carriage returns to the beginning of a new line in the time of one letter—that is to say in one quarter of a second. The time consumed in this way is therefore trifling.

The page-feed of the message forms is effected by rotating the typewriter platen through a fixed distance up to the starting-point of a new message. This is effected by a chain of gears and a single revolution clutch. A particular signal for paging up operates one of the crossbars, and this by suitable intermediate mechanisms trips the clutch so as to page up at the right moment. This paging up to a new message form is also very rapid, taking place in the time of two letters, or half a second. This is not counting the paging-up signal. Including the time of this signal, the time of paging up is three-quarters of a second. Page-printing in this machine, therefore, involves only trifling loss of time—on the average not more than 1½ seconds per message, and it saves all the labour and messing and waste of time involved in gumming a tape-printed message on to message forms, the process employed in the case of the Hughes, the Baudot, and other tape-printing telegraphs. Not only does page-printing in the Murray multiplex save time and labour, but the page-printed messages present a good appearance.

One argument used against page-printing by those who have been trained up in the use of tape printers like the Hughes and Baudot, is that as every correction and inquiry involves the use of a message form, there is great waste of message forms. Actual observation during the practical trial by the British Post Office showed that the loss from this source did not exceed 5 per cent. of the message forms used, and even this small loss could be halved by a little care and foresight. Also the writer has designed an arrangement by which inquiries and corrections (R Q's) can be obtained directly printed on a tape, thereby avoiding any waste of message forms, and also avoiding delay. Mention has already been made of the manner in which provision is made at the sending station for direct transmission of R Q's, even in the middle of the transmission of a message, by perforated tape. At the receiving station it is obvious that the R Q must not be printed on the message, the transmission of which has for the moment been interrupted. To get over this difficulty, a small reel of paper tape is provided on the typewriter carriage, and a strip of the tape is stretched along the platen just clear of the printing point. It remains out of the way during the printing of a message. If the operator at the distant station has an R Q to transmit direct, after he has thrown over the necessary switches, as already described, he transmits a special signal (secondary A) which causes the tape on the printer carriage to jump up into the printing position. The printing of the R Q then proceeds direct on the tape, the receiving operator pulling out a fresh portion of tape when necessary. The message form underneath is protected by the tape which receives the printing. When the R Q is finished the receiving operator pulls down the tape device out of the way, and the printing of the interrupted message in page form can be continued. This arrangement introduces some extra complications, and it is not necessary except in cases where it is desired to save every possible second of time. It is hardly worth while for the sake of saving a few message forms, especially when many R Q's of a brief character and unintelligible to the outside public can be printed at the foot of the page-printed messages, and then struck out with a pencil by the receiving operator.

An important point to be noted about this multiplex printer is that the five setting magnets have very little work to do. They have merely to perform a slight releasing operation. Consequently they can be successfully operated by a very small contact on the distributor. The value of this lies in cases where a considerable number of transmissions (4 to 6) may be required. Under such conditions the contacts on the distributors are necessarily very small.

Receiving Perforator.

With a multiplex printing telegraph system it is a comparatively easy matter to give three towns, A, B, and C, independent and simultaneous communication with each other on one telegraph wire. That is to say, it is not only possible but easy to arrange for A and C to be in direct communication while B is in direct communication with A and with C. More complicated arrangements can be made for simultaneous intercommunication between a larger number of towns, but the increased complexity soon puts a commercial limit on this arrangement. In the case, for instance, of town A transmitting telegrams through town B to various towns C, D, E, F, etc., one message going to one town and another message to another, there would be great difficulty in arranging any system of direct communication on one wire. In such cases there is another solution, namely, recording the messages in town B in the form of perforated paper tape. The messages can then be sent on automatically to any other city desired, and without any great complexity of mechanism. There is no continuous chain of mechanism, the breaking of any one link of which will cause the whole arrangement to collapse.

In the Murray automatic system all the received messages are first recorded at a high speed as perforations in paper tape, and from this perforated tape the messages are afterwards printed automatically. In the Murray multiplex a different kind of receiving perforator is provided. This instrument is shown in Fig. 16. It is essentially a Murray keyboard perforator tilted up on end and with the keys omitted. In place of the keys there are five small magnets which do the work of the keys—that is to say, they control selectively five small steel rods, which determine the holes to be punched in the paper tape. These five magnets correspond exactly with the five setting magnets of the multiplex printer (see Fig. 8). Each of these five setting magnets

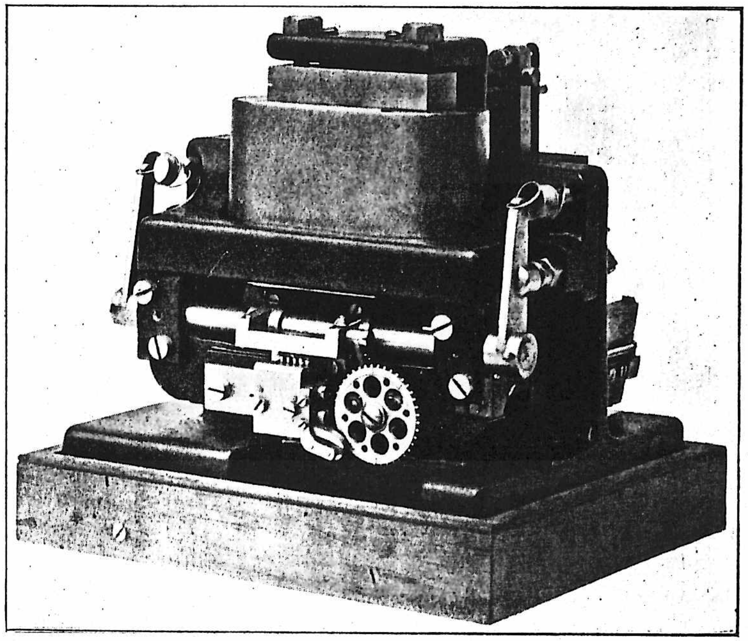


Fig. 16.—Murray Multiplex Receiving Perforator.

of the receiving perforator are placed in series with the corresponding one of the five setting magnets of the printer. The punching magnet of the receiving perforator is operated by the same impulse as that operating the printing magnet (Fig. 8) of the printer. On the printer there is provided a switch to throw the receiving perforator into or out of action by means of a signal from the distant station. If the sending operator at the distant station A has a message which requires to be transmitted at station B to, say, station F, he transmits a special signal which throws over the switch in the printer at station B. This puts the receiving perforator in action. The message is then recorded as perforations in tape by the receiving perforator at the same time as it is being printed in page form by the printer. At the end of every message the page signal, in addition to turning up a fresh telegraph form, automatically cuts out the receiving perforator. Consequently only messages requiring retransmission are perforated, and the sending operator has control over this operation at the distant station. As there is a printed message produced at the same time as the perforated tape, a glance at the printed message will show whether it has been correctly received. If it has been received correctly, then it can be automatically retransmitted to its destination by means of the perforated tape. If the message has not been accurately received, it can be corrected and sent in the ordinary way by manual instead of automatic retransmission. That is to say, it can be perforated again correctly on a keyboard perforator. In this respect the receiving perforator and tape retransmission present a decided advantage over the methods of direct communication between several towns, because any breakdown of the receiving perforator leaves all the ordinary working mechanism intact, and transmission can proceed in the ordinary way. This multiplex receiving perforator offers two main advantages in addition to that just mentioned, namely, (1) the message is printed and also perforated simultaneously, (2) only messages requiring retransmission are perforated. The others are printed only.

Preparation of Message Forms.

It is obvious that in a page-printing telegraph printing direct from the received signals, it is necessary to have some positive and automatic method of throwing out the finished message and feeding up a new message form to the right printing point. This may be done in two ways: (1) By feeding from a pile of cut forms, or (2) by means of a continuous roll of message forms. During recent years a number of devices have been perfected for feeding in separate sheets of paper one after another automatically into printing machines. There are undeniable advantages in this cut form plan, but the cross motion of the typewriter carriage presents serious obstacles to its employment in printing telegraphs. There is also the consideration that occasionally a message form may fail to feed into the printer, and the corresponding message would not be recorded. This would entail delay and repetition, and in some cases confusion and possible loss of a message or delivery of a message twice over. The continuous roll feed is free from these objections, but it entails preparation of some kind beforehand. Some slit or perforation has to be made in the paper band at the top of each message form to ensure positive feeding in of the forms to the right printing point. The messages have also to be cut apart with a pair of scissors or by other means. The arrangement adopted in the Murray multiplex may be described as a compromise between the two methods. Cut forms are employed, but they are lightly tacked together with dextrin so as to overlap. They are also perforated along their sides like cinematograph films, so as to ensure positive feeding up to the point for starting the message. This arrangement works well, and it has the advantage that the receiving operator has merely to pull off the messages as they are finished. There is an absolute minimum of trouble in this respect. For the preparation of the message rolls beforehand, a punching tool is employed, which perforates 8 to 10 messages simultaneously. This is a quick and simple operation and a large number of messages can be perforated at trifling cost. Pasting the messages together into continuous rolls also presents no difficulties. The work can be done by a boy quite rapidly by hand on a table without any mechanism; and in cases where large quantities are needed, a machine has been made to turn out the rolls quickly and cheaply.

TIME STAMP AND PRESS COPIER.

In the case of printing telegraphs handling a large number of messages, a time stamp saves a good deal of labour, and such an instrument is of special value in the case of a system like the Murray multiplex, where there is a possibility of one receiving operator attending to two printers, each producing 80 or more messages an hour. There is now at least one good time stamp on the market, and it is probable that such instruments will come into extensive use in connection with printing telegraphs during the next ten years. The time stamp will print on the telegrams instantly the date and time of reception, the number of the circuit, and any other particulars, including a number or other mark identifying the operator receiving and checking the messages. Actual experience has shown that an operator can easily check 120 messages an hour, and it is possible to check 150 an hour. With the aid of a time stamp it is believed that it would be easy to check 150 to 160 messages an hour. That is to say, except during times of great pressure, one operator would be able to attend to two multiplex printers, each turning out about 80 messages an hour.

There are a number of excellent wet-press copiers now in commercial use, and in time wet-press copying will overcome the trouble about keeping a copy for record of telegrams issued to the public.

With a good multiplex printing telegraph such as that just described, and with a time stamp and press copying, the labour cost of telegraphy will be reduced to about the lowest point possible.

RESULTS WITH MURRAY MULTIPLEX.

It is too early yet to say positively what results can be obtained with the new Murray multiplex system, especially as there are still a number of detail improvements to be made. A complete installation has only recently been completed for the British Post Office, and is now being installed between London and Manchester. Prior to this, an experimental set, giving one transmission only, was made by the British Post Office, and tried for about six months between London and Birmingham. The results were surprisingly good. The sending operators were two girls without previous experience on typewriter keyboards, and yet within one month they were each punching from 40 to 45 messages an hour. After about three months' practice each of these two girls succeeded in perforating 100 messages in one hour. Excluding several days when there were interruptions and breakdowns due to imperfections in the experimental apparatus, and excluding several days when traffic was light, the average number of messages on the one channel or transmission of the multiplex was over 80 per hour. On several days during busy hours the average exceeded 100 messages an hour. On one day, for instance, during three consecutive hours from 10 a.m. to 1 p.m., the numbers were 104, 126, and 102 messages per hour.

APPENDIX.

Since writing the foregoing paper I have been favoured by the Direction General of Russian Posts and Telegraphs with an official letter giving some interesting information in regard to the employment of the Murray automatic system on the telegraph line between St. Petersburg and Omsk. The letter, translated into English, is as follows:—

"In reply to your letter of 28th February, 1911, concerning the adaptation of the Murray apparatus to the telegraph line Omsk—St. Petersburg, the Direction General has the honour to inform you that this line has a length of 3,557 kilometres [2,224 miles], and has three repeating stations, namely, at Riazan, Samara, and Tcheliabinsk, arranged at the following distances: St. Petersburg—Riazan 865 kilometres [541 miles], Riazan—Samara 872 kilometres [545 miles], Samara—Tcheliabinsk 1,004 kilometres [628 miles], Tcheliabinsk—Omsk 816 kilometres [510 miles].

"The line is of iron wire and measures six millimetres [0·236 inch] in diameter.

"The line is worked duplex in an entirely satisfactory manner, and it is not necessary to revert to simplex except in the case of very bad atmospheric conditions.

"The regular operation of the Murray automatic apparatus on the St. Petersburg--Omsk line was inaugurated on the 19th April, 1908.

"The speed of transmission in each direction with the Murray automatic system, working duplex, is from 56 to 60 words a minute.

"The speed of transmission by the Wheatstone system on the same line did not attain more than 30 words a minute (six feet of tape), rarely 35 words (seven feet of tape), and under the very best conditions, and then only during very short periods of time, 40 words a minute (eight feet of tape).

"The foregoing practical results show that the effective speed of transmission on this line is far below the theoretical speed obtained by calculation. This difference appears to be due not only to atmospheric conditions, but also to the influence of the auto-induction of the line, and, above all, to the influence of the reciprocal induction of neighbouring wires running parallel with this line over long distances."

The words in parenthesis ( ) occur in the letter, but the words in brackets [ ] have been inserted by me. It will be seen from the facts given in the letter that the Murray automatic system has nearly doubled the carrying capacity of this St. Petersburg—Omsk line compared with the Wheatstone, which was formerly employed on it. Satisfactory duplex working on such a long line is remarkable, and should be a matter of encouragement to other Administrations with very long lines. It will be seen that the Murray automatic system has been in successful commercial use on this line for three years. The speeds are given in words per minute. These speeds are reckoned on the basis of five letters and a space equal to a letter per word. That is to say, they correspond to six typewriter letters or their equivalent space. The speeds of 56 to 60 words a minute are therefore equivalent to 336 to 360 letters per minute. The Wheatstone speeds are on the same basis.

DISCUSSION.

Major O'Meara.

Major W. A. J. O'MEARA: Some of us remember the paper on this subject which Mr. Murray read some five or six years ago. He has now told us of the advances which he has made since that time. I sincerely congratulate him on having turned his attention to the Baudot principle. Many inventors of printing telegraphs have an idea that the ordinary message consists of about one thousand words, and consequently they turn their attention, in developing systems, to dealing with these long messages. Mr. Murray has, fortunately, had some practical experience of the working of British telegraphs. Therefore what Mr. Murray tells us is really based on practical experience, and he realises that there is a more profitable field for invention if the problem is dealt with from the point of view of the actual messages which form the great bulk of those which have to be transmitted in this country. I entirely agree with him that the telephone will, in the future, be a feeder for the telegraph system. I think this problem of the telegraphs has to be very carefully considered, since we may come to a state of affairs when we shall only have long-distance telegraphs. In that case, we should have to take care of the line (which is the costly part of the system) and we should have to develop a system which will make the best use of the "line-time" in connection with messages the majority of which average eighteen words. Mr. Murray has shown us how we can make very much better use of the "line-time" by the printing telegraph as now developed by him than is possible with other systems.

Major O'Meara

When in America recently I had an opportunity of discussing this subject with experts of that country. Some people have an idea that the use of a transmitting tape involves waste. If, however, they give the matter careful consideration, I think they may alter their opinion. If a telegraph operator, especially with the page-printing system, makes a mistake, one of two things has to be done: either the message has to be rejected at the receiving end, or a correction has to be made. Now it is felt that a correction which appears on the blank form which goes to the public is a mistake, because, unfortunately the public are rather suspicious; and if they see a correction they suspect cooking. A transmitting tape at least reduces the liability to errors. In America, I observed that the whole message was rejected at the receiving station if a mistake were observed, and that the message was re-transmitted. Such procedure certainly involves waste of the "line-time." I am inclined to think that in connection with all these high-speed systems the tape is the proper thing, especially if that tape can be inspected and, if necessary, rejected before it is put through the transmitter. By that means, I think, the greatest use will have been made of the "line-time."

Mr. Higgins

Mr. C. HIGGINS: I wish, first, to congratulate Mr. Murray upon the improvements which he has effected in his printing telegraph machine. In regard to mistakes arising from confusion of the shillings and pence separated by a diagonal line with the numerator and denominator of fractions separated by a diagonal line, we do not experience any trouble in this connection, as is shown in the example of our Stock Exchange tape (Fig. A); the shillings and pence are separated by a diagonal line, and the numerator and denominator of the fraction by a horizontal line, which effectually prevents mistakes. It must be remembered that there are two distinct spheres of activity into which the printing telegraph can enter, and in which the requirements are entirely different, viz.: first, the transmission of messages, and secondly, the distribution of news. This latter is the one branch of telegraphy which demands as essential an apparatus recording in Roman characters. In regard to Major O'Meara's suggestion that the telephone will supplant the telegraph for short-distance work, surely he does not include in that category the "Distribution of News."

Mr. Higgins.

Consider the case of a certain service of ours where some 500 subscribers require some item of news instantaneously. We cannot picture 500 telephones and their attendants being brought in to supplant our apparatus, which effects the necessary transmission with celerity and accuracy, and provides a record from one transmitter operated by one operator, who could transmit equally well to 1,000 subscribers, and that upon apparatus requiring no skilled attention.

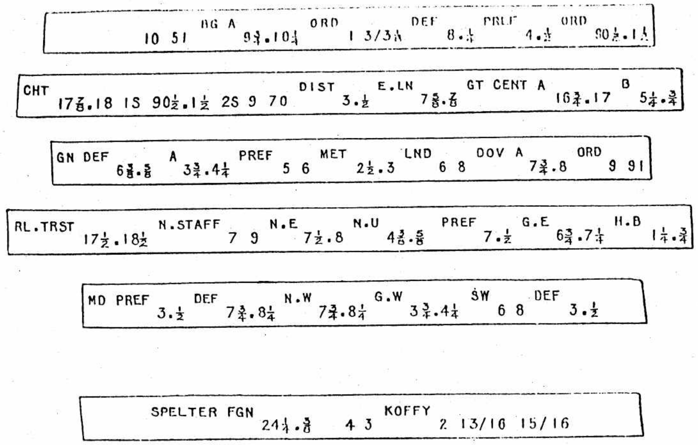

BG A 10 51 9¾.10¼ ORD 1 3/32 DEF 8.¼ PREF 4.½ ORD 90½.1½
CHT 17⅞.18 IS 90½.1½ 2S 9 70 DIST 3.½ E.LN 7⅝.⅞ GT CENT A 16¾.17 B 5¼.¾
GN DEF 6⅜.⅝ A 3¾.4¼ PREF 5 6 MET 2½.3 LND 6 8 DOV A 7¾.8 ORD 9 91
RL.TRST 17½.18½ N.STAFF 7 9 N.E 7½.8 N.U 4⅜.⅝ PREF 7.½ G.E 6¾.7¼ H.B 1¼.¾
MD PREF 3.½ DEF 7¾.8¼ N.W 7¾.8¼ G.W 3¾.4¼ SW 6 8 DEF 3.½
SPELTER FGN 24¼.⅜ 4 3 KOFFY 2 13/16 15/16

FIG. A.

Naturally, we sacrifice speed a little to effect such multiplicity of transmission, and the specimen of tape shown represents a speed of 50 words per minute from the automatic transmitter (6 letters per word); we cannot afford to utilise intricate apparatus requiring skilled attention at every receiver. We utilise instruments which must be relied upon to work when placed in a subscriber's office, and simplicity is the keynote of this class of apparatus. The work of the Exchange Telegraph Company is greatly increasing, and last year the aggregate number of words reached 650,000,000 on the instruments under our own control, and a great number on Exchange Telegraph Company's instruments employed to work the services of other news agencies.

Mr. Mansbridge.

Mr. G. F. MANSBRIDGE: In regard to the matter of the telephone assisting the telegraph, or the one acting as handmaiden to the other, I quite agree with Mr. Murray and Major O'Meara that there must be some assistance from the one to the other, but as to the extent of this I should like to utter a word of warning. I think that the telephone can never do a great deal in the way of feeding the telegraph, because the principle on which messages are sent over a telephone line is fundamentally different from that employed with the telegraph. Mr. Murray has given one indication in his paper of that difference when he refers to the difficulty of telegraphing Chinese messages. The difficulty arises from the fact that Chinese writing consists of ideographs, and that ideographs, other than those comprised in the Morse alphabet, cannot readily be transmitted by alphabetical signals. In the case of the telegraph the system of transmission rests on the same foundation as our system of writing, *i.e.*, the message is transmitted by spelling out the words letter by letter. In telephonic transmission, however, complete words—*i.e.*, practically ideographs—are sent through in bulk, and the moment it becomes necessary to transmit an unfamiliar ideograph or word, the system breaks down and recourse has to be had to the telegraphic method of spelling. But even this does not entirely get over the difficulty inasmuch as the telephone is but an inefficient device for transmitting with certainty isolated and unconnected letters—contrasting most unfavourably with the telegraph in this respect—and so in such cases resort has to be made to the quaintly primitive device of transmitting letters by means of words. For example, to transmit the commercial abbreviation "cif" over the telephone it might be necessary, on the score of accuracy, for the sending operator to say "cif: *c* for cat, *i* for ink, *f* for father." To take an illustration from the paper, on page 493 the author gives a code message. I can fancy the dismay of any operator having to receive that code telegram over the telephone. Although that message is perhaps an exceptional case, yet, if we take a hundred commercial telegrams, we should find very many phrases or names which offer much the same difficulty. It comes to this, therefore, that while the telephone may be useful for the message of the type "I shall not be home to-night," I do not think it will be of any great use for ordinary commercial telegrams. The situation as I view it may be summed up by saying that while the telephone is a highly efficient method of communication between principal and principal, its efficiency for commercial purposes—in which accuracy must have pride of place—drops enormously as soon as an intermediary has to be employed. Mr. Murray has paid a compliment to the Baudot system by employing that code for some of his apparatus, and I was therefore the more surprised to find Baudot working referred to as monotonous. The only basis which I can see for the suggestion is that sending on a Baudot keyboard involves a minimum of mental and physical strain; such "monotony" surely tends to the well-being of the operators.

Mr. Ryan.

Mr. F. RYAN: There is only one point to which I should like to draw attention, and that is the use of the keyboard perforator. I should like to know what the experience of others has been with this instrument. The experience of the Cable Company, with which I am connected, has not been quite so fortunate as the author's. We issued a certain number of these instruments about two years ago, and the reports from all stations were that there was a good deal of strain in the typing of code messages, and the percentage of errors was certainly increased. We have recalled those keyboard perforators, and have

Mr. Ryan.

converted them for working with a 12-key instead of the usual 52-key board. We do not quite know what the results will be.

Mr. Evershed.

Mr. S. Evershed: I notice that to all telegraphists the counting of the words in a telegram seems to be a regular nightmare. I suggest that the sender of a telegram should be forced to count the words, or, rather the letters, in his telegram. This can be done in such a way that he would not be aware of the fact that he was doing anything of the sort. All that is necessary is to have the telegraph form ruled in horizontal lines which are divided by vertical strokes into compartments, each compartment being intended to contain a single letter or digit. At regular intervals along the lines the cost in pence would be printed, so that neither counting of words nor reckoning of cost would be required. Writing in compartments is not difficult, and it has the great advantage that the writer is compelled to adopt a legible and rather copybook hand. A further advantage of compartment writing is that since the cost of the telegram is based upon the number of letters the present difficulty with regard to what the author calls Siamese-twin words disappears altogether. My scheme sounds a little complicated and possibly a little ludicrous, but is not the less fitted for a Government Department for all that.

Mr. Stubbs.

Mr. A. J. Stubbs: I am interested to see that Mr. Murray has arranged a device for temporarily changing the keyboard perforator into a transmitter. This was done by Carpentier, of Paris, two or three years ago for the Baudot, but I had no idea that Mr. Murray had adapted it to the Murray Multiplex. Perhaps a word of emphasis is worth giving in connection with the latest instrument that he refers to—the arrangement for receiving simultaneously a printed page and a perforated slip. I anticipate that that would be an extremely useful device in the circumstances which the author describes. Supplementing Major O'Meara's remarks with regard to the slip *versus* page printing, I think Mr. Murray rather anticipates that criticism in regard to the faults made by the operator who is preparing the slip; but no device can anticipate the faults which are introduced by line faults in transmission. So that (no matter how carefully a slip may be prepared) with a type-printing device there will always be errors introduced by momentary faults on the line, and it is these which make page printing apt to appear defective. I have no doubt that it is evident to nearly all engineers that the point of slip printing in this connection is that all defects can be easily cut out by the operator, during the process of very rapidly mounting-up the slip as it is received.

Mr. Judd.

Mr. W. Judd: In our cable system we have had very little occasion to use apparatus of the sort described by the author, and I do not suppose that this particular system, or any one exactly similar to it, will be adopted on long cables. But in any system that we do adopt, I fancy we shall insist on retaining the old Morse alphabet or the variation of it, the cable code alphabet. Supposing the new perforator or printing apparatus breaks down, we want to have the power of reverting to our old and well-tried recorder system, without a moment's delay, so that the same automatic tape punched out at the other end of the line shall be at once available for use in connection with our standard apparatus. We should feel lost if we had to adopt another language, so to speak, and became in a way bilingual at a moment's notice. It would be troublesome, to say the least of it. I was very interested to read Mr. Murray's remarks on the traffic aspects of the system. There are very great difficulties introduced in all these matters, because in a printing telegraph, particularly in a page printer, considerable risk is run of having mutilations and errors introduced into the page, which are difficult to correct. The tape printing is, no doubt, distinctly the best method at the present time at any rate, on account of the ease with which corrections can be made. Even then, the difficulties are not entirely overcome. There is the trouble, with the slip system, of gumming it on a delivery form, of getting the wet copy, and of the chances of the gum oozing out from the slip, thereby causing the flimsies to stick together. Still, no doubt, these difficulties will be overcome. With regard to the tape being perforated at the receiving end ready for onward transmission, there are a good many difficulties from the traffic point of view. We are hoping, before very long, to adopt such a machine for use on cables. We have been using one designed by Mr. S. G. Brown many years ago in connection with his relay. That worked up to a certain point, and we now hope to get one which will come into general use. It is in experimental use at present. The mechanical difficulties are far less than the traffic difficulties. All messages, at any rate on cables, carry a running number. These messages take a new number at each transmission, and it is obviously impossible to perforate a new number on the received slip. A way out of that difficulty has to be found, and the way we are hoping to get over it is to use one running set of numbers, say, between London and Adelaide, another between London and Bombay, and so on. These details may not be of much interest, and I only mention them to show that new methods bring a lot of difficulties in their train. No doubt surprise is felt that new apparatus is not at once adopted. It does not seem to be understood that new methods bring a lot of problems with them which have to be solved before they can be used commercially.

Mr. Judd.

Mr. Bell.

Mr. J. Hume Bell: The author refers to the bad handwriting of the general public as being partly responsible for the reduced speed of working on keyboard perforators. With this statement I agree. The full advantage of increased output which might reasonably be expected from the use of keyboard instruments will not be secured until an improvement in handwriting, especially of business messages, is insisted upon. Keyboard operators, who can work at 60 to 80 words per minute from typed or printed matter, are compelled to adopt a very much slower speed when dealing with badly written telegrams. I am sorry Mr. Murray has stuck to page printing in preference to printing on slip. Page printing involves the use of more complicated apparatus and necessitates the adoption of one type of message form. Against

Mr. Bell.

the economy in operator labour must be set additional mechanical attention. I should like to point out a serious disadvantage which must result if the present coloured message forms are given up. There are in use, in the Central Telegraph Office, five kinds of forms, each of a different colour. This colour scheme enables the boys engaged in collecting the messages from the instrument table racks to effect a primary sorting whilst carrying them to the distributing tables. This materially reduces the time taken in handling the messages within the office. With a slip-printing telegraph instrument the slip can be gummed on the existing forms, so that the present method of dealing with messages need not be altered. Mr. Murray refers to receiving perforators for re-transmission purposes. An extension of their use in this direction is desirable. Some two or three years ago a Creed receiving perforator was in use in the Special Section of the Central Telegraph Office. Prior to its installation it was customary for a certain news message of 1,000 or 1,200 words in length, which was received from Newmarket daily, to be recorded on Morse slip, written up by hand, re-perforated by hand, and then transmitted to a provincial office. These operations took about an hour. When the message was received on a Creed receiving perforator the time taken was reduced to ten minutes, and operator labour equal to about five man-hours saved. I agree with Mr. Murray that, provided capable operators are in control of the apparatus, the further introduction of printing telegraphs will tend to reduce the number of errors. Some time ago I saw in a German journal the following particulars as to the number of errors per hundred messages:—

Morse slip writing	0·019
Morse sounder	0·011
Hughes printer	0·004

Mr. Noble.

Mr. W. NOBLE: Major O'Meara has referred to the fact that the author was able to deal with this question of printing telegrams better because of the knowledge of practical working gained in the British Post Office. I always thought, after coming in contact with Mr. Murray in the Post Office, that it would have been in the interests of the Department, as well as of Mr. Murray, if he had at the outset spent six months continuously in the telegraph galleries, there to see the actual working of the different systems, and the operating as it is in actual practice. There is no doubt Mr. Murray would have foreseen and avoided many of the difficulties he was up against at a later date. The author, on page 454, refers to the Baudot and Hughes as being used for inland work in France and Germany, and for Continental work in this country. I think it would be interesting for the members to know that the British Post Office is extending the use of these instruments for inland work, and has recently installed a Baudot quadruple duplex between London and Birmingham. The result is so satisfactory that no doubt the use of the Baudot will be extended in this country when more apparatus is available. With regard to the Hughes, a few years ago there were no Hughes duplexes for inland work; but, at the present time, there are twelve working between London and Manchester, Liverpool and Glasgow; so we are following the lead of the Continental countries in this respect. On page 460 the author says that the printing telegraph is absolutely a commercial question. I hope Mr. Murray comes to this opinion after his experience with the British Post Office, because, if so, he will no doubt agree with me that it will be unnecessary to have a special telegraph authority to deal with the telegraphs. Mr Murray's automatic system has not been referred to during the discussion, and, as he says a good deal about it in his paper, it may not be out of place for me to make a few remarks upon it. On page 460 Mr. Murray says the three main points dealing with printing telegraphs are: first, a saving of labour; second, a saving of line; and, third, a saving of time. I do not know whether it was the introduction of Mr. Murray's system into the British Post Office that caused the Post Office to return to its old love, the Wheatstone, but, in any case, trials have been made with what is known as "Systematic" Wheatstone, and the results have been highly satisfactory. As most of the members will, no doubt, be aware, until recently the method of Wheatstone working involved the use of the hand perforator, and, at the receiving end, the messages were written up by hand. Now the Department is adopting keyboard perforators, which give a much higher speed than the ordinary hand perforator, and at the receiving end it is now adopting the practice of the cable companies, namely, instead of writing up the slip, to paste it on telegraph forms. The great advantage of this will be evident when I state that in many of the large centres the percentage of what are known as "X" messages is about 70 to 75. Ordinarily these messages come off the Wheatstone, are written by hand, and then transmitted to the next station. Nowadays, in the Systematic Wheatstone, these messages are pasted in the Morse slip, taken to the instruments, and forwarded by the operators from the Morse slip. My point is this, that it is much cheaper to use the Wheatstone in this way for the whole 100 per cent. of messages, since approximately 70 to 75 per cent. of them have to be re-transmitted, and are equally well re-transmitted from the Morse code, because this is less costly, and quite as reliable as printing telegrams. The "S" messages can be typed from the Morse slip. Furthermore, I should like to point out that the Wheatstone is largely used by the British Post Office for news work, and, therefore, there is always Wheatstone apparatus to spare, so that if one set breaks down we can transfer to another. With a special type-printing telegraph it is always necessary to have a duplicate set available, and this is costly. In a paper which was given by Major O'Meara at the first International Telegraph Conference at Budapest, it was mentioned that in a recent trial the saving of line and labour resulted in favour of the Wheatstone, and as regards time the two systems gave equal results. I should like to refer to the new apparatus. I like the new instrument, and if it fulfils all that is expected of it—and I hope it will—it will be a valuable addition to the

Mr. Noble.

Mr. Noble.

apparatus in the British Post Office. There is, however, one thing I rather doubt, namely, whether Mr. Murray will get a continuous forty words per minute on this instrument. The Baudot gets about thirty on an average, and I shall be very much surprised if this new instrument goes much above that figure.

Before concluding, I should like to refer to one or two rather Utopian ideas of Mr. Murray. For example, he says on page 458 the system of the future will, no doubt, be for a merchant to call up on his telephone and ask to be put through to the telegraph operator in order that he may dictate his telegram. I think that is a condition we are never likely to meet with, because a merchant, in the first place, will be sure to have his telegram written out or typed before he sends it over the telephone, and I do not think the merchant will spend his valuable time in re-dictating that message, especially as we know that the sending of telegrams over the telephone is a slow process. That it is impracticable in London will be gathered from the fact that at present at most of the offices in inner London thousands of messages a day are sent by pneumatic tube. In one case from one office 2,500 messages are sent into the Central Telegraph Office. The sending of this number of telegrams over the telephone cannot be imagined by practical officers. The aggregate delay would be serious and the number of telephone lines required would be great. I should like the members of this serious Institution not to take too literally the telegraphic blunders which Mr. Murray has put into his paper. The one about the blistering of pigs is well known. It is rather too much to believe that the intelligent and usually well-educated Irish operator would really send out such a telegram. The same applies to the joke about the mistake of "Almighty" for "Admiralty."

Mr. Harrison.

Mr. H. H. Harrison (*communicated*): I am not sure that there is not also a field of application for printing telegraphs to railway work. Telegraph traffic on a railway nearly all relates to the movement and disposition of rolling stock. On a large railway system with a great variety of vehicles, code words are used to denote the different classes. The messages usually start on their journey as "phonograms," and are very slowly handled. While it is not conceivable that type-printing would be suitable for handling long-distance railway telegraph traffic, there might be some advantage in using a simple type of printing telegraph between the various local offices radiating from an important telegraph office, and which are at present inefficiently served by telephones. There is no reason why the telephone should not still be used for conversational purposes, the printer being superimposed on the telephone loop. For military purposes, also, there seems to be a field for the employment of printing telegraphy. I am sorry that Mr. Murray condemns Esperanto. I should have thought that an International language would have helped the printing telegraph inventor. I can confirm what Mr. Murray says as to the mechanical or automatic way in which telegraph operators can work. When I was in the Central Telegraph Office about twenty-four years ago I used to be able to send a message with my right, and sign and time the messages simultaneously with the left hand, and this was not an uncommon accomplishment. The adoption of the Lacour wheel to driving a Baudot distributor is, in my opinion, a step in the right direction. It simplifies Baudot gear considerably, and should give much steadier running. The difference between direct and tape transmission is rather surprising when one reflects that with a keyboard transmitter the cadencing is much easier. It would be interesting if Mr. Murray would give his reasons for using the Blickensderfer printing mechanism on the multiplex printer only when the same mechanism is used on the high-speed automatic Buckingham-Barclay printer. The paper raises the question, not yet definitely answered, as to the relative advantages of page and tape printers. The page printer must always be more complicated than the tape instrument. It has a larger number of parts, has additional functions, and is therefore subjected to much greater wear and tear. It is also more costly to install. Maintenance costs for a given output will largely settle the matter. There are, however, other aspects than mere cost, installation, or running. The blank is ejected from the page printer ready for issue to the public, while with the tape printer an additional process is necessary.

Mr. Murray.

Mr. Donald Murray (*in reply*): The discussion that has taken place shows that not the least of the practical difficulties in the way of printing telegraphy is the conservative tendency of officials and the public. Fortunately there is a famous old engineer named Anno Domini, who is on the side of progress, and in due course his decisions will settle all controversy.

What Major O'Meara says about the advantages of perforated tape transmission of messages confirms my experience, and I am glad, also, that Major O'Meara agrees with me in thinking that in future there will be increasingly close co-operation between the telegraph and telephone. Some of the other speakers seemed to be doubtful on that point. Mr. Mansbridge, for instance, mentions the trouble in telephoning difficult words and figures which are so numerous in commercial messages. The difficulty certainly exists, but telegrams are telephoned every day, and it is too late now to maintain that the telephone cannot transmit anything that can be telegraphed, provided always that the telephone line is sufficiently short to give clear speaking. In saying that the Baudot direct transmission is monotonous, I was simply repeating what Baudot operators have told me. Actual trials have proved beyond question that a free typewriter keyboard is much easier and less monotonous than direct transmission with a cadence. Experience has taught me to agree with practically all that Mr. Judd says about printing telegraphs in connection with ocean cables. The conditions are very severe, and it seems to be a necessity to retain the Morse or cable code alphabet. The point mentioned by Mr. Judd about numbering messages on cables is an interesting illustration of the practical difficulties in the path of telegraph inventors and innovators.

Mr. Murray.

In regard to Mr. Ryan's remarks about the use of typewriter keyboard perforators by the Eastern Telegraph Company, the conditions in the cable service are undoubtedly very unfavourable for typewriter keyboard instruments. The difficulty about code words and figures can be overcome by proper training; but with cable stations scattered all over the world, it would appear to be almost impossible to give the training required, except at considerable expense extending over several years, and in any case the advantage to be gained is not very large. Mr. Higgins's automatic tape transmission for stock and news tickers is a very interesting development, and is directly in accordance with the arguments and experience in favour of automatic transmission in other branches of telegraph work. In reply to Mr. Harrison, the use of the typebar is necessary for high-speeds, because it is much more rapid than any typewheel, and its use at a high speed involves much less strain.

Several speakers referred to the question of tape-printing *versus* page-printing, and two arguments were advanced in favour of tape-printing. (1) Mr. Stubbs pointed out the advantage of being able to cut out all errors from the printed tape, so that no corrections appeared in the message as delivered. (2) Mr. Hume Bell pointed out the advantage of being able to paste the printed tape on to various kinds and colours of message forms. Dealing first with the argument mentioned by Mr. Stubbs, I may point out that if all errors are to be eliminated by cutting them out of the tape-printed messages, much delay will be involved. For instance, take the telegram: "Arriving tomorrwo at 4 p.m." This contains a very frequent error, namely, a transposition of letters. Surely it is not necessary to ask the sending station to re-telegraph the word "tomorrow" in order that it may appear in the message free from correction. Similarly, we have such mistakes as "Londom" for "London," and thousands of other obvious errors of the same kind. Are we to waste time and labour, and delay delivery of messages, for such trifles as these, when a stroke of the pen can put them right? Tape-printing certainly does not give messages free from correction, except at the expense of delay and waste of labour. Page-printing with invisible correction of errors before transmission meets the objection about errors as far as practical requirements demand, and the saving of time and labour by page-printing is very considerable. Actual experience at the British Post Office shows that an operator can paste up on the average about 200 British tape-printed messages on to telegraph forms in one hour, provided he does nothing else. If he also checks the messages, his output is much reduced. With a completely automatic page-printing telegraph like the Murray multiplex, the whole of this work is done by the machine. Taking a circuit exchanging 2,000 messages a day on a page-printing telegraph, the calculated saving of labour would therefore amount to 10 man-hours per day. The actual saving for various practical reasons is probably considerably more than this, and there is ground for believing that the saving of labour on such a circuit with page-printing will amount to about one operator at each end of the line. The saving of time is also of importance. Pasting up 200 messages an hour means a delay of 18 seconds per message. The Murray multiplex printer does this work in less than 2 seconds. The saving of time by page-printing therefore averages not less than a quarter of a minute per message. With a page-printing telegraph, also, the messages are ready for checking the moment they are printed and paged up. With tape-printing, at least several words must intervene between the printing and the pasting-up. That represents several more seconds of time lost compared with page-printing.

Mr. Murray.

In regard to the second point, raised by Mr. Hume Bell, namely, the convenience of pasting printed tape on to various kinds and colours of message forms, that difficulty is met with ease by the use of rubber stamps with different coloured ink-pads. There is no more difficulty for the operator to select the proper rubber stamp than to select the proper coloured message form, and there is the very considerable advantage of uniformity—a single message form throughout the service. As Mr. Bell points out, the percentage of errors in telegrams is quite small, but I think the figures he quotes refer to errors complained about by the public, that is to say, errors that passed unnoticed by the checker. I believe errors detected and corrected vary from about 1 per cent. under favourable conditions to about 10 per cent. in unfavourable conditions. Mr. Bell's figures, however, illustrate quite well the superior accuracy of printing telegraphs compared with manual telegraphy.

Mr. Noble referred to the introduction of the Hughes on inland circuits in Great Britain; but the introduction of the Hughes on busy circuits seems to me to be a retrograde step. The Hughes type-printer in an improved American form was once largely employed in America, but it is a good many years since its use was abolished by the Western Union Company. Instead of the Hughes, the Western Union has now about 60 circuits equipped with the Buckingham-Barclay perforated-tape-transmission page-printing telegraph. These Hughes machines on busy inland circuits in Great Britain will certainly be superseded before long either by the Baudot or the new Murray multiplex or automatic, or by some other of the more efficient modern printing telegraphs. Mr. Noble also referred to the newly established Baudot circuit between London and Birmingham, the solitary inland Baudot circuit in Great Britain. That undoubtedly is a step in the right direction, and it smooths the path for the introduction of the Murray multiplex, which may be described as a modernised Baudot. But the establishment of the first Baudot circuit in Great Britain in the year 1910 does not appear to me to be a sign of much enterprise on the part of the British Post Office. The Baudot system has been in successful use in France for 30 years, and there are now several hundred Baudot circuits in France, Italy, and neighbouring Continental countries. Russia has about 50 Baudot circuits. India and Brazil have had several in use for some years. Germany has had several Murray automatic circuits in daily commercial use for some years, and Great Britain has not one, although

Mr. Murray. there are three or four British circuits on which it could be applied with advantage. In Russia they have been working two very successful Murray automatic circuits for several years, one of them a truly remarkable long-distance circuit, and yet British telegraph engineers cannot show one Murray automatic circuit at work. It is true the British Post Office is getting a new installation of the Murray automatic for London to Dublin, but that is the total result of eleven years' dabbling with the subject.

The chorus of self-congratulation that has arisen recently from some British telegraph officials about "systematic" Wheatstone working, is certainly surprising to onlookers. The obvious comment is that if Wheatstone working in Great Britain has not been "systematic" until recently, then that fact is not one to be proud of. "Systematic" Wheatstone is just common-sense Wheatstone. The cable companies have used the same plan for a long time past, and I saw "systematic" Wheatstone, just as Mr. Noble describes it, being worked on a considerable scale in St. Petersburg and Moscow five years ago. A large number of typewriters were also in use for typing up the Wheatstone tape messages. At that time I do not think there was a solitary typewriter in use for telegraph purposes in all Great Britain. Even now there are very few. What Mr. Noble says in favour of the Baudot does not harmonise happily with his enthusiasm for "systematic" Wheatstone. Judging by what is going on in more progressive countries, I think it is a safe prophecy to say that, with the exception of news work, there will not be much "systematic" Wheatstone left in Great Britain in another twenty-five years. It will take something more than "systematic" Wheatstone to arrest the progress of the Baudot and the Murray and other modern printing telegraphs. It is only fair to say that the large majority of British telegraph officials are capable, highly trained men, progressive, energetic, and far-seeing; but their efforts are clogged by prejudice and old routines.

There is one statement made by Mr. Noble that calls for elucidation. He says that in the paper given by Major O'Meara at the first international telegraph conference at Buda Pest, it was mentioned that [in a comparative trial of the Murray automatic, the Wheatstone, and other systems] the saving of line and labour resulted in favour of the Wheatstone, and as regards time the two systems gave equal results. In this matter Mr. Noble's memory seems to have misled him. The information furnished by Major O'Meara to the Buda Pest Conference stated that "The Murray output per operator per hour worked out at 31 per cent. higher than the Wheatstone," and the table of figures given to the conference by Major O'Meara showed that during the trial the Wheatstone handled 12,239 messages and the Murray automatic 12,994, and the number of messages per operator per hour was 27·2 for the Wheatstone and 35·7 for the Murray automatic. These were the actual results of the trials. On the other hand, if Mr. Noble arrives at his statement about the superiority of the Wheatstone by including the estimate of engineering costs of the various systems, then it must be pointed out that the estimate of engineering costs given at the Buda Pest Conference is utterly misleading and unreliable. It actually charged 3 per cent. sinking fund on interest as well as on capital, and 15 per cent. establishment charges were added not merely to cost of maintenance but also on to interest on capital and on to sinking fund (the latter already swollen by charging it not merely on capital but on the interest on capital), and on top of all that 2½ per cent. for contingencies was added to interest on capital, cost of maintenance, sinking fund, and establishment charges. In view of the composition of this truly remarkable sinking fund, business men can form their own conclusions about the accuracy of the estimated engineering costs. The trials of the various systems are also no longer recent. They took place three years ago, and Major O'Meara mentioned at the Buda Pest Conference that the maximum speed of the Murray automatic during the trials was 95 words a minute. Since that trial three years ago the Murray automatic system has been greatly improved and the Wheatstone has not. The speed of the Murray automatic printer has been increased from 100 up to 200 words a minute, and the practical working speed of transmission has been raised to 150 words a minute. As a further practical comment on Mr. Noble's "saving of line and labour in favour of the Wheatstone," I may draw attention to the official information supplied to me by the Russian Post and Telegraph Administration in regard to the working of the Murray automatic system between St. Petersburg and Omsk. It will be found published as an appendix to this paper. It shows that the Murray automatic has considerably increased the carrying capacity of the line compared with the Wheatstone.

Mr. Murray.

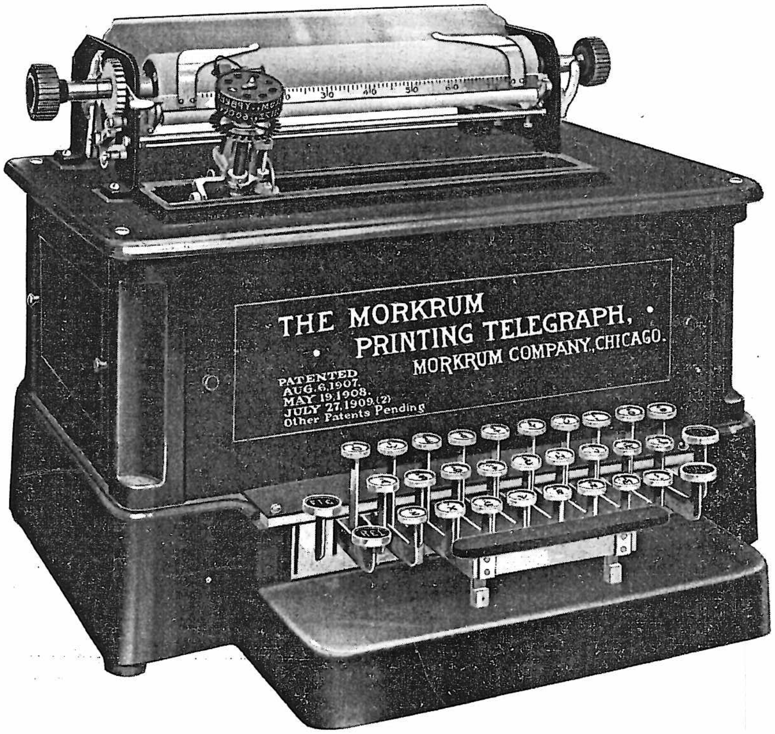
The President: I ask you to give Mr. Donald Murray a cordial vote of thanks for his valuable paper.

The resolution of thanks was carried by acclamation.

84-36
WESTERN UNION
TELEGRAPH MUSEUM
60 HUDSON ST.
NEW YORK, N. Y.

Directions for Operating

The Morkrum Telegraph Printers



MORKRUM COMPANY
General Offices
717 Railway Exchange Bldg.
CHICAGO

Copyright, 1911
by
Morkrum Company, Chicago, Ill.

NMAH 205/75/3

to rest on the casting the carriage is liable to bind and cause piling of letters. The allignment of figures and letters is made by means of the adjusting screw; to set this, write a few letters and figures, and adjust the screw until the figures are in line with the letters.

MORKRUM PRINTER CODE

	LETTER	1	2	3	4	5	LETTER	1	2	3	4	5	
1	A	+	+	−	−	−	Q	+	−	−	+	+	12
2	B	−	−	+	−	+	R	−	−	+	+	−	3
3	C	−	−	+	+	+	S	−	+	−	+	−	6
4	D	+	+	+	−	−	T	+	+	−	+	−	7
5	E	+	−	+	+	−	U	−	−	+	−	−	2
6	F	−	+	−	+	+	V	+	−	+	+	+	5
7	G	+	+	−	+	+	W	+	+	−	−	+	1
8	H	+	−	−	−	−	X	+	−	+	−	+	9
9	I	+	−	+	−	−	Y	−	−	−	−	+	14
8	J	+	−	−	−	+	Z	−	+	+	−	+	13
10	K	−	+	−	−	+	[illegible] '	−	−	−	−	−	14
10	L	−	+	−	−	−	SPACE	+	+	+	−	+	4
11	M	−	−	−	+	−	FIG.	−	+	+	+	+	15
12	N	+	−	−	+	−	RLS	+	+	+	+	+	16
13	O	−	+	+	−	−	BACK	+	+	+	+	−	16
	~~P~~	~~−~~	~~−~~	~~+~~	~~+~~	~~+~~	LINE	−	+	+	+	−	15
11	P	−	−	−	+	+							

Figure 21—Morkrum Code

The polarities of the five selective time intervals are shown by table in Figure 21, but it is of course understood that each signal is preceded by a positive starting interval.

0

P — — — ++

G. R. Benjamin

Bulletin No. 2
August 1912

Directions for Operating

The Morkrum Telegraph Printers

IMPORTANT NOTICE

This book of directions is issued for the exclusive use of telegraph officials and attendants, directly interested in and accountable for the operation of the Morkrum Printers.

It is not intended for circulation, and is not to be given out for that or for any other use; and being copyrighted, the copying of, or publication of the whole, or any part thereof, is prohibited, without the written consent of the Morkrum Company.

All the circuits and mechanisms herein shown, or described, are fully covered by patents granted, by patent applications allowed and applications pending, and the rights of the Morkrum Company under the same will be fully protected.

MORKRUM COMPANY
General Offices
717 Railway Exchange Bldg.
CHICAGO

Copyright, 1912
by
Morkrum Company, Chicago, Ill.

NMAH 265/75/3

because of a chip between armature and pole piece or because of dirty contact points.

If **space bar is struck** and printer sticks, see if space magnet operates. If not, examine wires leading to spacer coils.

If spacer magnet operates look at wiring and contacts of main break relay and main break.

If **lining signal fails,** test in same way as for spacer. The lining magnet is operated the same as spacer, in series with main break relay which closes circuit to main break.

If main break relay operates but main break does not, see wires leading to main break and also see that plunger stop is not too low.

Morkrum Printer Code

A	.	.	3	4	5	Q	.	2	3	.	.
B	1	2	.	4	.	R	1	2	.	.	5
C	1	2	.	.	.	S	1	.	3	.	5
D	.	.	.	4	5	T	.	.	3	.	5
E	.	2	.	.	5	U	1	2	.	4	5
F	1	.	3	.	.	V	.	2	.	.	.
G	.	.	3	.	.	W	.	.	3	4	.
H	.	2	3	4	5	X	.	2	.	4	.
I	.	2	.	4	5	Y	1	2	3	4	.
J	.	2	3	4	.	Z	1	.	.	4	.
K	1	.	3	4	.	.	1	2	3	4	5
L	1	.	3	4	5	SPACER	.	.	.	4	.
M	1	2	3	.	5	FIGURE	1	.	.	.	.
N	.	2	3	.	5	RELEASE	.	.	.	.	.
O	1	.	.	4	5	BACKING	.	.	.	.	5
P	1	2	3	.	.	LINING	1	.	.	.	5

The Numbers after the Letters indicate the Cams and Locks operated for each Signal